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ABSTRACT

An experiment was conducted that compared the teaching effectiveness of a computer assisted instructional module and a lecture-discussion. The module, Predator Functional Response (PFR), was developed as part of the SUMIT (Single-concept User-adaptable Microcomputer-based Instructional Technique) project. A class of 30 students was randomly divided into two groups, one which ran the module and the other which attended a lecture on the same material. Both groups were then given a posttest, and the results analyzed using analysis of covariance and individual item analysis. No significant differences were found between the groups. The implications of these results to microcomputers and to teachers are discussed, with the conclusion that although microcomputers are effective teaching instruments, they should be incorporated into the classroom situation with care and forethought. Provided in appendices are PFR documentation, performance objectives, the posttest, the random division program used to separate the students into two groups, lecture transcript, analysis of covariance, and PFR program listings (for Apple microcomputers). (JN)

DEVELOPMENT AND EVALUATION OF THE SUMIT MICROCOMPUTER MODULE ENTITLED 'PREDATOR FUNCTIONAL RESPONSE'

by

Mark B. Shaltz

done as part of the

SUMIT

SUMIT COURSEWARE DEVELOPMENT PROJECT
DEPARTMENT OF BIOLOGICAL SCIENCES
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DEVELOPMENT AND EVALUATION

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A REPORT

submitted in partial fufillment of the requirements

for the degree of

MASTER OF SCIENCE IN THE BIOLOGICAL SCIENCES

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As the final acknowledgement, this entire report is dedicated with many warm thanks to my Lynn, who not only added much spice to my existence, but also made my work, and indeed my life, seem worthwhile.

ABSTRACT

An experiment was conducted that compared the teaching effectiveness of a microcomputer module and a lecture. A class of 30 students was randomly divided into two groups, one which ran a module and the other which attended a lecture on the same material. Both groups were then given a posttest, and the results were analyzed using analysis of covariance and individual item analysis. No significant differences were found between the two groups. The implications of these results to microcomputers and to teachers were discussed, with the conclusion that microcomputers are effective teaching instruments, but they should be incorporated into the classroom situation with care and forethought.

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INTRODUCTION

Although computers have been a part of our society for over 25 years, they are just beginning to become popular in the educational field. This is not to say that no one has shown an interest in the subject of computer applications in education. To the contrary! As far back as 1958 individuals like Alfred Bork, then a physics professor at the University of Alaska saw the potential of computers in teaching and began research on the possibilities (Kiester, 1978).

The number of individuals interested in computers in education grew as computers became more popular in the 1960's. In that decade the number of schools having computers increased six-fold (ACM Bulletin, 1979). Unfortunately these computers were utilized mainly for administrative purposes, so the teaching applications of the computer lagged far behind this tremendous growth in computer popularity.

There are numerous uses of computers in education. The Illinois Series on Education (1979) listed eight different ways computers could be used in teaching, with others (Roecks, 1981; Watts, 1981) later adding to that list. Even so, the computer is not utilized nearly as much as its potential suggests. For example, although computers have applications in virtually every curriculum, over half of

the student use of computers in higher education today is in only three departments: computer science, engineering, and business (Molnar, 1981).

One of the areas of study that does not make extensive use of computers is the biological sciences. The reasons for this, according to Tocci (1981), may stem from the belief that biology requires fewer quantitative analyses than such subjects as physics and engineering. But Tocci stresses that there are many uses of the computer other than for quantitative analysis, and several are directly applicable to the biological sciences. He blames the lack of computers in biology teaching on the teachers themselves, saying that many lack training in the area of computers, so they either do not know about the computer's potential, or else they are suffering from "computerphobia" (Jay, 1981). Many teachers have almost no concept of what a computer is or what it is capable of doing. Another related fear is that the computer will soon replace teachers. This is a largely unfounded fear. Frank Clement (1981) studied the situation and came to the conclusion that there is no evidence that computers will replace teachers in education. He even postulated that the need for teachers who can use computers and also for teachers who can help develop high quality educational software may be responsible for the opening of more teaching jobs.

In 1971 semiconductor manufacturer Intel Corporation

developed the microprocessor chip (Marbach and Lubenow, 1982), which eventually had a far-reaching effect on educational computing. This is because the microprocessor chip made possible the development of the relatively inexpensive modern microcomputer, a small, stand-alone computer equipped with a keyboard and a TV monitor usually with graphics capabilities.

Suddenly any school could own its own computer for a tiny fraction of the cost of previous computers. Before microcomputers became available in 1977, the standard in education was the large time-sharing computer, which consists of two parts; the central processing unit (CPU) and the remote terminals. The CPU is the actual computer, where data is stored and processed. The remote terminals are keyboards used to communicate with the computer. These terminals could be located at various places and connected to the CPU by telephone lines.

Educators were quick to recognize the advantages of the microcomputer over the time-sharing computer system. According to McIsaac and Baker (1981), the major advantages are cost, user controllability, and convenience.

It is not unusual for a time-sharing computer system to cost several hundred thousand dollars. A microcomputer costs as little as two thousand dollars, which is within the budget of many more schools. Additionally, a time-sharing computer costs a large amount of money to run

and maintain. Each time a program is run it costs money, which tends to discourage use of such a computer system. A microcomputer costs almost nothing to run, so its use can be encouraged with no fear of mounting large computer processing bills.

The user of a microcomputer has much more control of the entire system than does a user of a time-sharing computer. On a time-sharing computer system the user must contend with problems beyond his/her control, such as computer down time and defective connecting telephone lines. Microcomputers are decentralized so that each one is a separate unit. There are no telephone lines connecting them and no problems with other users on the system at the same time. The microcomputer user does not have to be concerned with computer down time, or with waiting in line for the CPU to run a program, or with keeping user identification numbers secret.

Related to controllability is convenience. Microcomputers tend to be more convenient than time-sharing systems. Because microcomputers are decentralized, the user works with the entire unit. This eliminates such inconveniences such as i.d. numbers and long waiting periods both to run a program and to receive its output. Also more convenient is the fact that microcomputers have no running or processing costs. They can be used often and at any time of day with no worries of the resulting bill.

The running costs of a time-sharing system can vary at different times of the day and can get quite expensive, especially if the terminal ~~is~~ hooked to the CPU via a long-distance telephone connection.

Many agree that an additional advantage of the microcomputer for educational applications is its color graphics capabilities, which allow it to use graphs, charts, pictures, and even animation (Bork, 1980; Bork and Franklin, 1979; Smith, 1979; Zinn, 1979). This allows the microcomputer to do more than process numbers and display text, thus adding a new dimension to its applications.

It is the combination of all these advantages which make the microcomputer an attractive package in education. For example, there is a large time-sharing system that has been developed that shares many of the advantages of the microcomputer. It is called PLATO (Programmed Logic for Automatic Teaching Operations) and is available to many colleges and universities. PLATO is essentially a computer terminal and TV screen connected to the CPU via long-distance telephone lines. PLATO has excellent graphics capabilities and immediate, interactive feedback to user inputs. But its major drawback is cost. According to Gerald Gleason (1981), a single terminal hooked to PLATO would cost a school \$6000 a year. With such a high cost, PLATO cannot compete with the microcomputer for the educational computing market.

With all of their advantages, microcomputers are rapidly becoming popular in education. But one of the major obstacles to their growth at this time is the long-time establishment of the time-sharing systems already in schools. A school will be hesitant to spend money on microcomputers when it already is equipped with a large time-sharing system. But this is not a permanant hindrance to the spread of microcomputers. For example, a 1978/79 study done by the Minnesota School District Data Processing Joint Board (ACM Sigcue Bulletin, 1980) culminated in the recommendation to phase out time-sharing in favor of microcomputers in Minnesota schools.

With the sudden popularity of microcomputers, the educational community has been beset by a couple of major problems. Most teachers have little computer knowledge. They do not know how to use computers or what computers can do. This is termed "computer illiteracy" and is one of the most serious problems associated with the educational computer boom (Dickerson and Pritchard, 1981). Another very serious problem is that microcomputer development has far exceeded its software development (Gleason, 1981). Software refers to the programs that can be run on the computer. Many teachers have ideas concerning how to use microcomputers in their classes, but no software has yet been developed for their needs. So although microcomputers are becoming available for use in the classroom, these two

problems, the large number of teachers who are not computer literate and the lack of educational software, limit the microcomputer's use.

In the face of problems such as these, a project was initiated at Michigan Technological University. The two year long SUMIT project (Single-concept User-adaptable Microcomputer-based Instructional Technique), headed by Dr. J. D. Spain and funded by the National Science Foundation, began in the spring of 1980 and produced educational software related to the biological sciences for the Apple II Plus microcomputer. Each microcomputer program, or module, dealt with a single subject in the areas of ecology and general biology.

The modules were designed to be used as a supplement to a biology or ecology laboratory. Experts tend to agree that Computer-Assisted Instruction (CAI) used in addition to laboratories or classroom lectures is the best application of CAI in courses (Alpert and Bitzer, 1970; Clement, 1981; Jenkins, 1976; Tsai and Pohl, 1978; Tsai and Pohl, 1981; Visonhaler and Bass, 1972).

CAI is defined by Oliver and Scott (1978) to be "the direct interaction of a student with a computer through an alphanumeric and/or graphics communications terminal for an instructional purpose." With this in mind, the SUMIT modules could be termed CAI modules because they were written with the idea that they would be run by students

who would interact with the modules.

User interaction with the microcomputer was felt to be a very important part of the learning experience, so all of the SUMIT modules allowed freqent user-computer interaction through questions and answers. Using the Apple microcomputer's graphics, this was extended to include an interactive graphics situation in which the user would experiment with equation parameters and observe how changes affect various curves and graphs.

SUMIT modules will not only help to alleviate the lack of educational software, but they also were designed to be used by all teachers, regardless of their degree of computer literacy. It requires no computer programming knowledge to run the modules. As an added feature, along with each SUMIT module comes a copy of documentation that explains simple ways that a user can modify the module. Therefore teachers need not be computer experts to run or modify these modules.

Each of the SUMIT modules underwent several formative evaluation procedures. Members of the SUMIT team constantly ran the modules throughout their development and offered suggestions and criticisms. The modules were also run by small groups of students in various ecology and biology courses at MTU. These students would each fill out evaluation forms, which were then used to further improve the modules.

Summative, or final, evaluation took place in animal ecology and general biology laboratories at MTU. The SUMIT modules were incorporated into the laboratory work, where the students would take a pretest, run the module, and then take a posttest to find if they improved after running the module. They also filled out evaluation forms to give the SUMIT team an idea of their attitudes, likes, and dislikes in relation to the computer work in laboratories.

The SUMIT team desired to evaluate a SUMIT module by comparing it to the traditional method of instruction. Since the modules were written to be part of laboratory experiences, the most relevant summative evaluation would be to use it as part of a laboratory exercise and test students' improvement. The question is, can they teach a student as effectively as traditional instruction (TI) techniques? It was decided to address this question through the summative evaluation of a SUMIT module.

The problem of this study was to determine the effectiveness of CAI using a SUMIT module by comparing it with a traditional method of instruction -- lecture-discussion.

RELATED LITERATURE

A review of the literature in the area of evaluating CAI revealed very little useful material. A number of individuals expressed the belief that CAI could teach as effectively as TI (Bork, 1980; Cunningham, 1979), but they never conducted any studies on the matter. Others carried out experiments that were very weak. For example, Morrison and Adams (1968) carried out a study on CAI vs. TI in German language classes. They claimed to have found the CAI group to be better in some skills, but no statistical analysis could be performed on the data due to the unstructured nature of their study. Different teachers taught different groups, plus some individuals changed groups midway through the study.

Weistheimer conducted a study of CAI supplemented laboratories vs. traditional laboratories and found that the CAI supplement group did significantly better on material covered on the computer (Jenkins, 1976). But his experimental method was faulty because the CAI supplement group put in four hours "overtime" to look at the CAI modules, while the traditional laboratory group put in no extra time. This gave unfair advantage to the CAI supplement group.

Gershman and Sakamoto (1981) carried out a large-scale study with the Ontario secondary school system. But

students were allowed to move from the CAI group to the TI group and vice versa, so their results were not conclusive.

Better studies with proper experimental design were also found in the literature (Alpert and Bitzer, 1970; Hollen, Bunderson, and Duham, 1971; Lewellen, 1971; Suppes and Morningstar, 1969; Tsai and Pohl, 1978; Tsai and Pohl, 1981; Visonhaler and Bass, 1972), but most were old -- pre-microcomputer era. Educational computing prior to the late 1970's tended to center more around drill & practice. It is questionable if these studies could provide any indication of the teaching effectiveness of the modern CAI simulation modules, because simulations and drill & practice are two very different uses of the computer.

Also, none of the studies found were conducted for a single CAI module. Instead they all were a test of learning over the course of a term or semester. All of these differences made it difficult to predict the results of a SUMIT module vs. TI comparison.

As a final note on this subject, two studies in the literature proved interesting. In 1978, Magidson reviewed the accumulated studies of CAI vs. TI and found that 55% of these resulted in no significant differences. The remaining 45% of the studies resulted in finding the CAI more effective than TI. Three years later, Burns and Bozeman (1981) published a similar review and found 40% resulted in no significant difference, 45% resulted in finding CAI more

effective, and 15% resulted in mixed results.

One should note two points. First, the latter review found 15% of the CAI vs. TI comparisons getting less than favorable results for CAI. Secondly, the studies were separated by three years, the exact time of the introduction and subsequent popularity of the microcomputer. Possibly in those three years the studies conducted involved microcomputers with more graphics and simulation modules. If this was true, then microcomputer simulations could be responsible for reducing the number of studies that found CAI to be effective, which would imply that either the software for microcomputers was of low quality, the studies were not run well, or that microcomputer simulations are not effective teaching devices.

METHODS AND MATERIALS

(This section outlines the development of the Predator Functional Response module, the lecture to which it was compared, and the posttest for the experiment. The population used, the experimental design for the lecture vs. CAI study, and the statistical methods to analyze the data are also described.)

A. Choice of the module

The SUMIT module entitled Predator Functional Response was chosen for a study comparing the teaching effectiveness of a CAI module and a lecture-discussion. This module concerned the topic of predator functional response and its relationship to prey recruitment. Briefly, predator functional response (PFR) relates the number of prey killed to the prey density in the surrounding environment in which that predator lives. If this is studied in conjunction with prey population growth, or prey recruitment, of an area, many interesting and potentially useful relationships can be discovered. For a more detailed look at prey recruitment-predator functional response, please refer to the PFR module documentation in Appendix A.

This module was chosen because I felt that students would not be familiar with the subject of PFR or the

graphical techniques used to plot the PFR curve. PFR is an important, but not widely taught concept, so most of the students had never been exposed to the material in the module before. New concepts decrease the probability that one student is at an advantage over other students, which is important in the proper evaluation of the effectiveness of a teaching method.

Another reason for using the PFR module was that it was written by the investigator conducting this study; thus he was familiar with the module and the subject matter. This assured that the instruction would be most effective and also eliminated the teacher confounding factor (this occurs when one individual develops teaching materials and another uses them to teach).

B. Development of the module

Initial development of a microcomputer module on PFR involved finding the right approach to the subject. The objective of this module was to take the student further into the predator-prey relationship than the Lotka-Volterra numerical relationships, and also to expose him to ways of graphing relationships other than the standard plot of "population as a function of time".

Many different methods of graphing PFR exist. Examples include plotting the proportion of prey killed per predator

as a function of prey density (Murdoch, 1973), and plotting the log of the number of prey killed per predator as a function of the log of the prey density (Real, 1979). The simplest method found, and the one used for the PFR module, was to graph the number of prey killed per predator as a function of prey density, a technique made popular by Holling (1959).

A microcomputer program was developed depicting prey recruitment and type III PFR (Holling, 1959) interactions. At this point the module's objectives were formulated for this module:

After running the PFR module the student should be able to:

1. identify and predict stability of prey density equilibrium points resulting from predator functional response.
2. predict and recognize the effect of changes in predator carrying capacity on equilibrium points.
3. compare the relative rates at which different starting prey densities approach a stable equilibrium point.
4. recognize the effect of hunter pressure on prey density equilibrium points.

It should be pointed out that these objectives are not the same as the final performance objectives that were

tested for in the study's posttest (these can be found in Appendix B). The list of objectives was changed and expanded throughout the development of this module as more was learned about PFR and the capabilities of the Apple II Plus microcomputer.

After a module was written and programmed on the Apple, formative evaluation began. This encompassed constant suggestions and subsequent improvements, followed by further suggestions for improvement. The formative evaluation for the PFR module roughly followed the guidelines outlined by Dick and Carey (1978). First the author and SUMIT team reviewed the module. After the suggested improvements were made, the module was run by a small group of students, the BL575 Advanced Animal Ecology class. Their suggestions were used to improve the module. Next a team of three SUMIT members who had a special interest in PFR was assembled. This team met twice weekly to review the module and offer suggestions and criticisms. Following this, a four-member committee created to supervize the graduate work of the PFR module's author ran the module and offered suggestions. Finally, a year after the formative evaluation began, four individuals knowledgeable in the field of predator-prey relationships (two of which could be considered "experts" in the subject of PFR) ran the module to check the accuracy of the material presented. No erroneous material was found, which

ended the formative evaluation of the PFR module.

C. Development of the lecture

A lecture was needed that was comparable to the PFR module in its objectives. Using the list of performance objectives developed for the PFR module (see Appendix B), a lecture-discussion was written by the investigator. This assured that both the lecture and the module covered the same material at the same level.

The lecture was approximately 40 minutes in length and used overhead projections for the graphs. Time was included in the lecture for student questions. After the lecture-discussion was written the author reviewed it to ensure that all of the performance objectives were adequately covered.

To obtain a permanant record, a videotape was made when the lecture-discussion was given to BL340 Animal Ecology. A written transcript was made from this videotape. This can be found in Appendix E.

D. Development of the posttest

A posttest was needed that would measure knowledge on the subject of PFR. The following format for the posttest was chosen:

-- The posttest consisted of multiple choice items because they can be scored objectively, yet have more discriminatory power than true/false items; plus they can be used to test for a variety of cognitive learning levels.

-- The posttest had 20 items. Past posttests used on other SUMIT modules had eight to ten items. For this study a longer test was developed to increase the reliability of the results.

-- A time limit was set for the completion of the posttest by the students. A time limit of 15 minutes was chosen so that it could be administered within the anticipated time constraints on the day of the study.

A posttest with this format was written that tested for the set of performance objectives developed for the module and lecture. Then it was evaluated by the members of the SUMIT team. Suggestions were made, which were used to improve the posttest.

As a final evaluation of the posttest, four individuals knowledgeable in PFR were asked to take the test and look for inaccuracies in the information

presented. They did this and offered several suggestions for improvement, which were incorporated into the final version of the posttest. A copy of the posttest used in this study can be found in Appendix C.

E. Description of the population

The fall 1981 BL340 Animal Ecology class was used to compare the PFR module to a lecture-discussion. 30 Students were enrolled and attending this course at the time of the experiment. These 30 students were divided randomly into two groups of 15. The random division permitted the assumption to be made that the two groups were representative samples of the population in their prior knowledge of the subject matter to be tested, so a pretest did not have to be given. The randomization was done by associating each student with a random number and then sorting the random numbers from lowest to highest. The students with the 15 lowest random numbers made up the group that would run the PFR module. The remaining 15 students would make up the group that would attend the lecture on PFR. This procedure was conducted on the Apple II Plus microcomputer. A copy of the program and results can be found in Appendix D.

F. Experimental design

One week prior to the experiment the students were informed where to report on the day of testing. On the day of the study, the lecture group attended the 40-minute lecture-discussion on the subject of PFR in their regular lecture room. At the same time, the module group met in their laboratory room and ran the PFR module. Each student used a separate microcomputer and was given 40 minutes to run the module. At the end of the 40 minutes both of the groups were brought together and administered the posttest on PFR.

G. Methods of analysis

Each student's posttest score and final course points percentage was collected. Analysis of covariance was applied to this data, using the final course points percentage as the covariate, to test the null hypothesis that the means of the adjusted posttest scores for the two groups were equal. The alternate hypothesis was that the two means were not equal.

In an effort to analyze the effectiveness of the posttest, test and item analyses were run. This was accomplished using a program entitled ITEM ANALYSIS (Fehlberg and Flathmen, 1969) on the UNIVAC computer. This

program calculated a variety of statistics, but the ones most useful to this study were the Kuder-Richardson Formula 20 reliability coefficient (KR-20), the item difficulty indexes, and the item biserial correlation coefficients.

The item difficulty index used was the fraction of students that answered the item correctly. It is a number between zero and one and is calculated by dividing the number of correct responses by the total number of responses for each item.

Item discriminatory power, the "ability to differentiate between students who have achieved well... and those who have achieved poorly" (Ahmann and Glock, 1981), and its difficulty index are related. Items with difficulty indexes around 0.50 generally have the maximum discriminatory power. Therefore a test with items in the range of 0.30 to 0.80 will have a high discriminatory power.

The Kuder-Richardson Formula 20, or KR-20, checks the internal reliability of the entire test. It is calculated using the following formula:

KR-20 = 1 - (SUMMATION (P(1-P)))/Test Variance

where P = each item's difficulty index.

The KR-20 uses item difficulty indexes to estimate consistency of student performance from item to item. The

KR-20 has a possible range of zero to one, but should be greater than 0.50 for any given test (Tinari, 1979). A value lower than this indicates that the test may be internally inconsistent.

The item biserial correlation coefficient has a possible range of minus one to one. It is calculated using the following formula:

BCC = (P(Mr - Mw))/(Z(Test Variance))

where Mr is the mean of the students answering the item correctly.

Mw is the mean of the students answering the item incorrectly.

P is the item difficulty index.

Z is the ordinate in the unit normal distribution corresponding to the proportion P .

Like the difficulty index, the biserial correlation coefficient is also related to item discriminatory power. It measures how well an item separated the good students from the poor ones. If an item is discriminating well, the mean test score of the students choosing the correct answer should be greater than the mean test scores of students who chose distracters (wrong answers). When this happens the biserial correlation coefficient for that item is high. If,

on the other hand, the poorer students chose the correct answer and the better students chose the distracters, that item is not operating properly, and the biserial correlation coefficient would be negative.

The lecture and module groups were compared item-by-item using a 2X2 contingency table with the rows equalling module and lecture, and the columns equalling the number that responded with the right answer and the number with the wrong answer: Chi-square values were calculated from these contingincy tables.

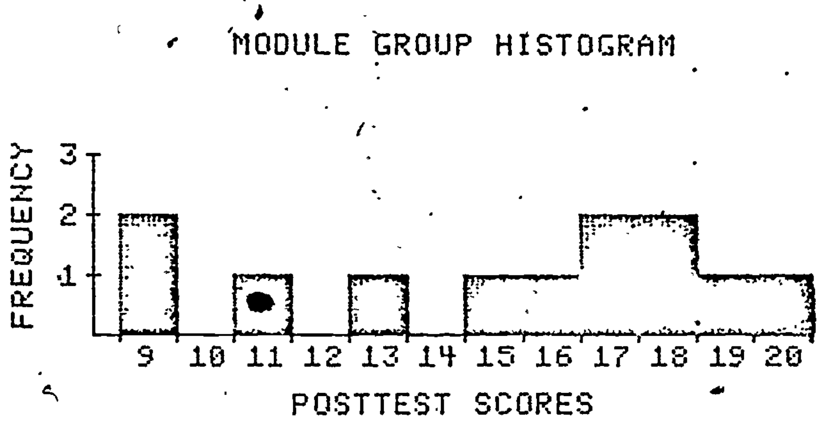
RESULTS

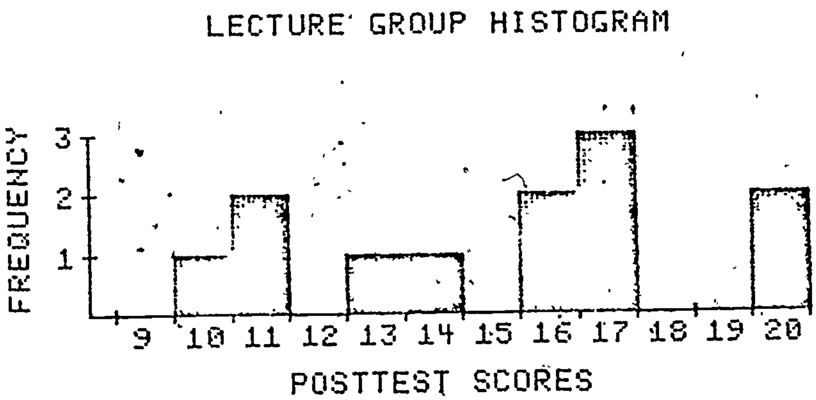
30 students were enrolled in BL340 Animal Ecology at the time of the experiment. It was hoped that sample sizes of 15 for each group, lecture and module, would occur, but several factors reduced this number. Two students from the module group were absent, reducing the module sample size to 13. In lecture, three students arrived late and missed enough material to possibly lower their posttest scores, so these students' scores were dropped from the data set, leaving 12 scores from the lecture group to be analyzed.

To use analysis of covariance to compare the lecture and module group means, a covariate was needed. The final course points percentages for the students in the study were used. At the end of the term the list of final points percentages was collected, and ~~it~~ was found that one student who had participated in the module group had later dropped the course. Thus he had no final points percentage, so his posttest score had to be dropped from the data analysis.

This left 12 students' data in each group. The complete final data set can be found in Appendix F. The posttest scores for the lecture and module groups were plotted on frequency histograms in Figure 1. Analysis of covariance was applied to the data collected (see Appendix F). The calculated F-value was less than one, so the null

FIGURE 1. Frequency histograms for the posttest scores of the module and the lecture groups.





hypothesis was accepted; the means of the adjusted posttest scores for the lecture and module group are not significantly different.

Table 1 summarizes the results of the test and item analyses. One will recall that the KR-20 formula measures the internal consistency of the test and should be greater than 0.50 . The KR-20 formula for the class posttest results was 0.80, which indicates a test with high internal consistency.

The difficulty indexes are listed by item in Table 1. One can see that half of the items in the class's posttest were within the acceptable range of 0.30 to 0.80 .

Biserial correlation coefficients are also listed by item in Table 1. Tinari (1979) suggested that items should have biserial correlation coefficients greater than 0.30 to be useful. Scanning the class data in Table 1, it can be seen that 16 items pass this criterion, which is a greater number than the number of items with the proper difficulty index. This means that for some items the difficulty index was not within the optimum range, but the item was still functioning by discriminating good students from poor.

When the lecture and module groups were compared item-by-item using a contingency table (Figure 2), it was found by calculating chi-square values that the two groups were not significantly different on any single item of the posttest.

TABLE 1. Posttest statistics. This table includes test means, standard deviations, and KR-20 values; plus item difficulty indexes and biserial correlation coefficients (BCC's).

	ENTIRE CLASS		LECTURE GROUP		MODULE GROUP	
Mean:	15.17		15.17		15.17	
st dev:	3.60		3.38		3.81	
KR-20:	0.80		0.81		0.87	
Item #	Diff Ind	BCC	Diff Ind	BCC	Diff Ind	BCC
1)	.417	.537	.417	.869	.417	.244
2)	.792	.878	.750	.689	.833	1.128
3)	.625	.781	.583	.649	.667	.921
4)	.792	.625	.667	.614	.917	.919
5)	.125	.851	.167	.996	.083	.721
6)	.958	.294	1.000	.000	.917	.323
7)	1.000	.000	1.000	.000	1.000	.000
8)	.833	.274	.917	.196	.750	.323
9)	.708	.604	.750	.932	.667	.356
10)	.958	.294	1.000	.000	.917	.323
11)	.667	1.008	.667	.826	.667	1.173
12)	.875	.382	.833	.241	.917	.621
13)	.958	.837	1.000	.000	.917	.919
14)	.958	.837	1.000	.000	.917	.919
15)	.542	1.001	.500	1.033	.583	1.103
16)	.750	.913	.750	.608	.750	1.186
17)	.917	.578	.833	.756	1.000	.000
18)	.875	.323	.833	.344	.917	.323
19)	.792	.962	.833	.653	.750	1.186
20)	.625	.717	.667	.614	.583	.810

FIGURE 2. An example of the two-by-two contingency table that was used to compare the module and lecture groups by item. The data in this figure is from item #4 of the posttest.

	RIGHT	WRONG	
LECTURE	8	4	12
MODULE	11	1	12
	19	5	24

DISCUSSION

A study comparing a CAI module and a lecture was conducted, and it was found by analysis of the data that there was no significant difference between the two in their teaching effectiveness. Although the results are limited to the population of this study, they can be used to consider some other aspects of microcomputers and their use in teaching.

First, how are the results of this study important to manufacturers of microcomputers? Microcomputers have been experiencing a boom in education without any evidence that they could be useful. All that existed were the "feelings" of a limited number of teachers that they could be used somehow. This study provides some evidence that microcomputer CAI modules can teach students as effectively as a class lecture. With this evidence more educational institutions may be willing to make purchases and thus make microcomputers more popular in the classroom. With their increased availability in educational institutions, their use will also increase with more teachers using them in more different ways.

An already existing problem that may temporarily become more acute is the lack of high quality educational software. If a sudden increase in microcomputer popularity in education occurs, the software problem will get worse. A,

large number of teachers will be exposed to microcomputers and will want to use them, but the software will be limited. CAI simulation modules take hundreds of hours to write, develop, and program. The lag time involved in developing educational software may put a severe pinch on the expanding needs of the educational computing community. Possibly, though, more teachers will develop their own software, and that may be the ultimate answer to the problem.

The next issue to be addressed is the significance of the PFR study to teachers. In the past many teachers were hesitant about using CAI in their classes, partially because they had no way of knowing if it was a useful means of teaching. The PFR study provides evidence that CAI modules can be effective in teaching certain topics (i.e., those that are simulation- and graphics-oriented). With this evidence possibly teachers will begin to make use of CAI modules to replace some lectures and/or to supplement others. The microcomputer has shown that it can be an effective instructional tool, so it should be used as such. The use of the microcomputer in a class will add variety to the learning experience, which will aid the student in understanding and recall.

One curriculum that has a wealth of simulation- and graphics-oriented topics is biology. Thus it is surprising that biology is one of the least frequent users of

computers in education (Magidson, 1978). In his text "BASIC Computer Models in Biology" (1981), Spain covers at least 50 mathematical models related to some aspect of biology, each of which could be the basis of a CAI module. Probably the main problems are related to computer illiteracy among biology teachers and a lack of educational software in the subject of biology. But with the SUMIT project and other similar courseware development programs, biology teachers will have more software to make use of in their courses, which may help alleviate the problem.

Does this study support the view that microcomputers can replace teachers? McCredie (1981) pointed out that the computer has decreased greatly in price at a time when the cost of supporting a faculty member has gone up significantly. He believes that the inexpensive price of computers in teaching will make them much more popular in the near future. But will they replace teachers?

The evidence is against it. Tsai and Pohl (1978) conducted studies in 1978 and 1981 comparing the teaching effectiveness of TI, CAI, and CAI supplemented TI. These were some of the first studies that included all three of the most important contrasts concerning CAI learning: TI vs. CAI, TI vs. CAI supplemented TI, and CAI vs. CAI suppemented TI. The results were that they found no significant difference between CAI and TI; but they also found that TI supplemented with CAI was significantly more

effective than either alone.

Some may argue that these studies prove that computers will replace teachers soon. But more evidence exists that this will not occur. Possibly the closest thing to a completely computer-instructed course that exists in the United States at this time is located at the University of California at Irvine (Bork, 1980). There an introductory physics course is taught through a series of PLATO simulation modules. But even this does not eliminate teachers because a summary lecture is given at the end of each week, plus if students consistently have problems on certain material in the CAI module, they are locked out of the module until they discuss the problem with the course instructor. So even with maximal use of CAI, teachers are needed to answer questions and pull together the material for the students.

That is the extreme case of CAI. Most investigators agree that totally computer-instructed courses are not the most effective use of computers in education; rather, CAI used to supplement laboratories and lectures is the best application (Alpert and Bitzer, 1981; Clement, 1981; Jenkins, 1976; Tsai and Pohl, 1978; Tsai and Pohl, 1981; Visonhaler and Bass, 1972). SUMIT modules were designed with this application in mind, and, although this study found the PFR module to be as effective as a lecture, the module was not designed to replace a lecture. CAI modules

may prove to be effective on their own, but any attempt to fit presently available modules together to completely replace a series of lectures would result in an unrelated set of subjects being taught with no connection among them. Therefore, microcomputers and their existing software do not threaten to replace teachers at this time.

In the opinion of this researcher teachers should look at the microcomputer as another learning device to be used to enhance their courses. Microcomputers provide the graphics and interactiveness necessary to teach some difficult-to-convey topics and should be used in conjunction with related laboratories and lectures.

The microcomputer is an effective learning aid, but it should not be looked to as an answer to all educational problems. It has its areas of application, like any other teaching aid. But several problems have to be avoided. I was involved with CAI modules from both a student and an instructor's viewpoint in the past year. From my experiences I have found that there is a danger of overusing CAI modules. This was also found by Tsai and Pohl (1978). It seems that any more than one module a week results in a severe loss in student interest. Therefore, possibly the most effective use of microcomputers would be as part of a multi-media exposure for the student, including such things as overheads, films, slides, videotapes, and field trips. In this way the microcomputer

could add to the richness of a course without becoming a hindrance through overuse.

For future research the module vs. lecture comparison could be improved in several ways. First, it could be repeated with larger sample sizes, which would strengthen the results and also provide possible replication of the results. Further development of the posttest would also be helpful. The posttest in this study contained many multiple-choice items with weak distracters. Better distracters would raise the reliability and discriminatory power of the test.

Also, an interesting addition to the experiment would be the testing of long-term retention of the material learned. By testing the students a week or more after the experiment, long-term retention of the material could be tested. This would be especially interesting, because past studies on retention of CAI learned material have found conflicting results (Alpert and Bitzer, 1970; Hollen, Bunderson, and Duham, 1971; Tsai and Pohl, 1981).

To conclude, a CAI module dealing with predator functional response was developed for the Apple II Plus microcomputer as part of the SUMIT microcomputer software development project. This module was used in an experiment comparing the teaching effectiveness of a CAI module and a class lecture. The 30 students in BL340 Animal Ecology at Michigan Technological University were randomly split into

two groups for the experiment. One group ran the PFR module, the other group attended a lecture on PFR. Immediately afterwards, the students took a posttest on the subject of PFR. The results of this posttest were analyzed, and no significant difference was found between the scores of the two groups. This indicates that CAI modules are useful devices for teaching.

LITERATURE CITED

ACM Sigcue Bulletin: Computer Uses in Education. 1979. Report: Evaluation of TICCIT. 13(3): 6-17.

ACM Sigcue Bulletin: Computer Uses in Education. 1980. From time-sharing to microcomputers: excerpt from 1978-79 annual report of the Minnesota School District Data Processing Joint Board. 14(2): 18-20.

Ahmann, J. S. and M. D. Glock. 1981. Evaluating student progress. Allyn and Bacon, Inc.

Alpert, D. and D. L. Bitzer. 1970. Advances in computer-based education. Science. 167: 1582-1590.

Bork, A. 1980. Computer graphics in learning. Journal of College Science Teaching. 9(3): 141-149.

Bork, A. and S. Franklin. 1979. Personal computers in learning. Educational Technology. 19(10): 7-12.

Burns, P. K. and W. C. Bozeman. 1981. Computer-assisted instruction and mathematics achievement: is there a relationship? Educational Technology. 21(10): 32-39.

Clement, F. J. 1981. Affective considerations in computer-based education. Educational Technology. 21(4): 28-32.

Cunningham, R. S. 1979. A statistic laboratory using computer graphics. Journal of College Science Teaching. 9(1): 31-33.

Dick, W. and L. Carey. 1978. The systematic design of instruction. Scott, Foresman and Company.

Dickerson, L. and W. H. Pritchard. 1981. Microcomputers and education: planning for the coming revolution in the classroom. Educational Technology. 21(1): 7-12.

Fehlberg, D. and Flathman. 1969. Item Analysis computer program documentation. University of Alberta.

Gershman, J. and E. Sakamoto. 1981. Computer-assisted remediation and evaluation: a CAI project for Ontario secondary schools. Educational Technology. 21(3): 40-43.

Gleason, G. T. 1981. Microcomputers in education: the state of the art. Educational Technology. 21(3): 7-18.

Hollen, T. T., C. V. Bunderson, and J. L. Duham. 1971. Computer-based simulation of laboratory problems in qualitative chemical analysis. Science Education. 55: 131-136.

Holling, C. S. 1959. The components of predation as revealed by a study of small-mammal predation of the European sawfly. Canadian Entomologist. 91: 293-320.

Illinois Series on Educational Application of Computers. 1979. Department of Secondary Education. University of Illinois.

Jay, T. B. 1981. Computerphobia: what to do about it. Educational Technology. 21(1): 47-48.

Jenkins, E. 1976. The potential of PLATO. Report on Teaching. 8(2): 6-9.

Kiester, S. 1978. It's student and computer, one on one. Report on Teaching. 10(1): 56-59.

Lewellen, L. 1971. Computers in the classroom. Journal of Educational Data Processing. 8: 33-38.

Magidson, E. M. 1978. Issue overview: trends in computer-assisted instruction. Educational Technology. 18(4): 5-8.

Marbach, W. D. and G. C. Lubenow. 1982. To each his own computer. Newsweek. 8: 50-56.

McCredie, J. W. 1981. Campus information processing: a new wave. Journal of College Science Teaching. 62(4): 6-11.

McIsaac, D. N. and F. B. Baker. 1981. Computer-managed instruction system implementation on a microcomputer. Educational Technology. 21(10): 40-46.

Molnar, A. R. 1981. The coming of computer literacy: are we prepared for it? Educational Technology. 21(1): 26-28.

Morrison, H. W. and E. N. Adams. 1968. Pilot study of a CAI laboratory in German. Modern Language Journal. 52: 279-287.

Murdoch, W. W. 1973. The functional response of predators. Journal of Applied Ecology. 10: 335-342.

Oliver, W. P. and G. F. Scott. 1978. CAI: the next twenty-two years. Information. 229-307.

Real, L. A. 1979. Ecological determinants of functional response. Ecology. 60(3): 481-485.

Roecks, A. L. 1981. How many ways can the computer be used in education? A baker's dozen. Educational Technology. 21(9): 16.

Smith, F. G. 1979. Continuing education with personal computers. Educational Technology. 19(10): 16-17.

Spain, J. D. 1981. BASIC computer models in biology. Addison-Wesley.

Suppes, P. and M. Morningstar. 1969. Computer-assisted instruction. Science. 166: 343-350.

Tinari, F. D. 1979. Item analysis in introductory economics testing. Improving College and University Teaching. 27(2): 61-67.

Tsai, S. and N. F. Pohl. 1978. Student achievement in computer programming: lecture vs. computer-aided instruction. Journal of Experimental Education. 46(2): 66-70.

Tsai, S. and N. F. Pohl. 1981. Computer-assisted instruction augmented with planned teacher/student contacts. Journal of Experimental Education. 49(2): 120-126.

Tocci, S. 1981. The microcomputer/biology 'interface'. Science Teacher. 48(5): 61-62.

Visonhaler, J. F. and R. K. Bass. 1972. A summary of 10 major studies on CAI drill and practice. Educational Technology. 12(7): 29-32.

Watts, N. 1981. A dozen uses for the computer in education. Educational Technology. 21(4): 18-22.

Zinn, K. L. 1979. Using the microcomputer: one university's experience. Educational Technology. 19(11): 54-55.

APPENDIX A

Predator Functional Response

Module Documentation

Following is a copy of the documentation that was written for the PFR module.

PREDATOR FUNCTIONAL RESPONSE

ABSTRACT

This module explores the interrelationships between prey recruitment and predator functional response curves. Equilibrium points are examined with respect to their numbers and stability. The effects of varying predator population size are explored. A method for estimating the relative time required for reaching equilibrium is discussed. The effects of hunter pressure on the predator-prey system are examined and discussed.

PREREQUISITES

Familiarity with S-shaped growth curves (such as the logistic equation). Previous exposure to predator-prey models, such as the SUMIT module entitled PREDATOR-PREY DYNAMICS.

OBJECTIVES

After running this program, the user will be able to:

a) identify and predict stability of prey density equilibrium points resulting from predator functional response.

b) predict and observe the effect of changes in the predator carrying capacity on equilibrium points.

c) compare the relative rates at which different starting prey densities approach a stable equilibrium point.

d) observe the effect of hunter pressure on prey density equilibrium points.

5. BACKGROUND

Solomon (1949) defined two categories of interaction between predators and their prey. He defined the predator NUMERICAL RESPONSE as the change in predator density in response to a change in the prey density. This would be exemplified in the Lotka-Volterra predator-prey models (Wangersky, 1978) where the predator population fluctuates in response to the number of prey (see Figure 1).

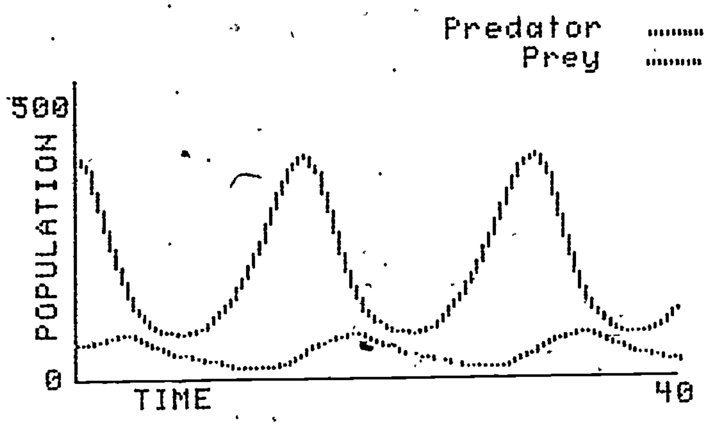


Figure 1. Example of a Lotka-Volterra predator-prey graph. A graph showing the cycling nature of the fluctuations of the predator population in response to changes in the prey population. This graph is an example of output from the SUMIT module entitled PREDATOR-PREY DYNAMICS.

Solomon hypothesized that predator eating habits also changed. He defined the predator FUNCTIONAL RESPONSE as the change in the number of prey consumed by individual predators in response to a change in prey density.

Predator functional responses are not as well studied as numerical responses, but play an important role in stabilizing prey density. Many times the numerical response of a predator may occur more slowly and also be dependent on the predator's functional response (Oaten and Murdoch, 1975).

There are three basic types of predator functional response curves, when the number of prey eaten by a constant number of predators is plotted versus prey density. The curves have the shapes shown in Figure 2 as defined by Holling (1959).

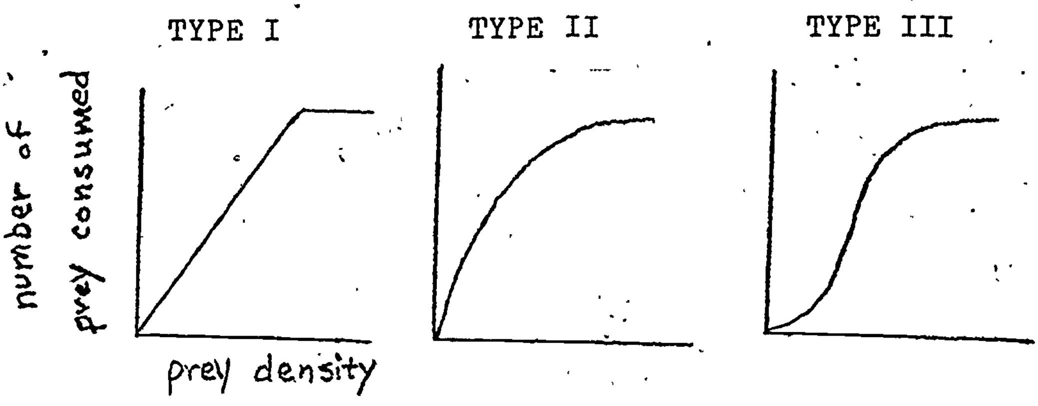


Figure 2. The three basic shapes of predator functional response curves.

All three curves in Figure 2 tend to level off. This is due to predator satiation. Satiation refers to the maximum number of prey that a constant number of predators can consume in a given time interval.

The type I curve represents a predator with a random search pattern and a rate of searching that remains constant at all prey densities. The number of prey consumed, then, would be directly proportional to the prey density, and a straight line graph would result.

The type II curve represents a predator whose rate of searching progressively decreases as prey density increases.

Possibly the most interesting is the type III predator response curve. One explanation that has been put forward for the sigmoid shape of the curve is that the predators are exposed to multiple prey species. The 'S' part of the curve is due to predator switching; that is, the predators consume a disproportionately larger number of the more abundant prey (Oaten and Murdoch, 1975). When one species of prey is scarce the predators concentrate on other sources of food. But as the density of that prey species increases, the predators recognize and consume a much larger number of them, which is reflected in the steep part of the curve.

Investigations done on type II and type III predator functional responses include Holling's work with predation on the pine saw-fly (1959); Manly, Miller, and Cook's experiments with Quail (1972); and Murdoch, Avery, and Smyth's guppies (1975).

Looking at the prey in the absence of any predators is helpful later in finding relationships between predators and prey. The growth curve of the prey population under such conditions will generally be S-shaped (Horn, 1968). Figure 3a shows a typical prey population growth curve.

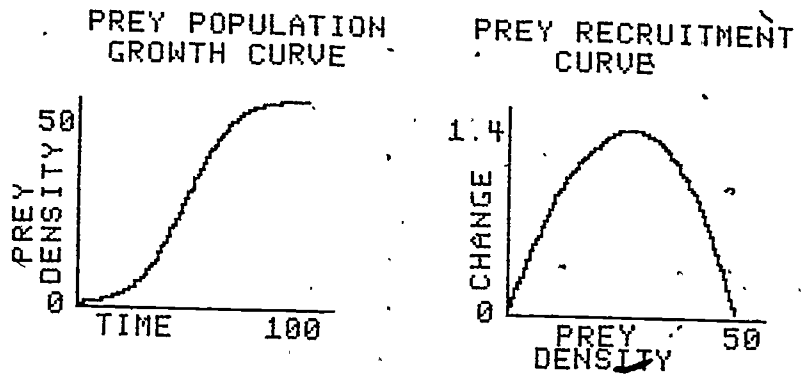


Figure 3. Example of an S-shaped growth curve (a) and the resulting recruitment curve (b) for a prey population. These graphs are an example of output from the SUMIT module entitled PREDATOR FUNCTIONAL RESPONSE.

To compare the growth of the prey with the predator functional response, the prey population growth must be graphed on the same axes as the functional response curve. When this is done, the graph in Figure 3b is the result. The curve in Figure 3b is called a prey RECRUITMENT CURVE. It represents prey births minus prey deaths that are non-predator related. It records the additions to the prey population graphed as a function of prey density.

If the predator of this prey species displayed a type III functional response, the curve plotted on the same graph as prey recruitment could look like that of Figure 4.

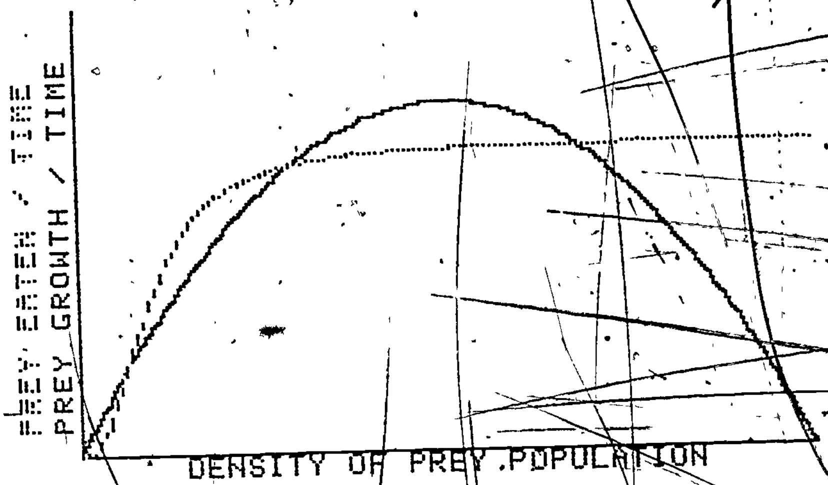


Figure 4. Prey recruitment and a predator type III functional response curve plotted on the same graph. This graph is an example of output from the SUMIT module entitled PREDATOR FUNCTIONAL RESPONSE.

Because the prey recruitment curve represents additions to the prey population and the predator functional response curve represents losses from the population, the points where the two curves intersect describe equilibria where the prey density will neither increase nor decrease. Where the prey recruitment curve is

APPLICATIONS

The SUMIT program entitled PREDATOR FUNCTIONAL RESPONSE is useful for showing some relationships between predator and prey. The number and stability of equilibrium prey densities can be studied using this program.

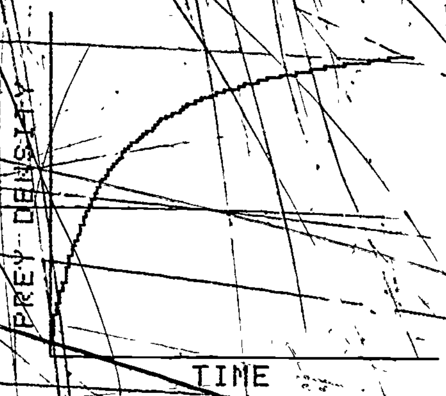
PREDATOR FUNCTIONAL RESPONSE introduces the user to different ways of representing predator-prey interactions.

Questions

1. The program discusses predator-prey relationships where three equilibrium points exist and also where one equilibrium point exists. Why do you think a two equilibrium point relationship was not discussed or simulated?

2. Hunter pressure is an example of what shape (type) of predator functional response curve?

3. Here is an example of a prey growth curve:



Given this curve, come up with the general shape of the prey recruitment curve for this population.

4. Would you think that predator functional response is usually a faster or slower process than predator numerical response? Why?

5. In the hunter pressure section of the program, the prey density ended up at the lower stable equilibrium point. Suggest how the prey density might be brought back up to the upper stable equilibrium point. Do you think that any of these suggestions are feasible for use in real life situations? Can you come up with examples where your suggestions are already being used?

LITERATURE CITED

Holling, C. S. 1959. The components of predation as revealed by a study of small-mammal predation of the European pine sawfly. Canadian Entomologist 91: 293-320.

Holling, C. S. 1973. Resilience and stability of ecological systems. Ann. Rev. Ecol. Syst. 4: 1-24.

Horn, H. S. 1968. Regulation of animal numbers: a model counter-example. Ecology 49 (4): 776-778.

Manly, B. F., P. Miller, and L. M. Cook. 1972. Analysis of a selective predation experiment. Am. Nat. 106: 719-736.

Murdoch, W. W., S. Avery, and M. E. B. Smyth. 1975. Switching in predatory fish. Ecology 56 (5): 1094-1105.

Oaten, A. and W. W. Murdoch. 1975. Functional response and stability in predator-prey systems. Am. Nat. 109: 289-298.

Solomon, M. E. 1949. The natural control of animal populations. J. Anim. Ecology 18: 1-35.

Wangersky, P. J. 1978. Lotka-Volterra population models. Ann. Rev. Ecol. Syst. 9: 189-218.

MODELS USED IN THE PROGRAM

This module is divided into four subprograms.

PRED FUNCT INTRO serves as an introduction and covers the transition from the S-shaped growth curve to the prey recruitment curve. Specifically, the standard logistic equation was used to plot the S-shaped curve.

dN / dT = R * N * (1 - N/K)

where:

R = intrinsic rate of natural increase
N = prey population size
K = prey carrying capacity
dN/dT = the change in the number of prey per unit time

The parameters used in this program are:

R = 0.1 K = 50 N = 0.5

The logistic curve is a plot of prey population size (N) as a function of time. The prey recruitment plot is the change in prey density (dN) as a function of prey density (N).

PRED FUNCT1 introduces the predator functional response curve and plots it on the same graph as its prey's recruitment curve. The recruitment curve is again calculated with the logistic equation, using the following parameters:

R = .01, K = 100.

The predator functional response in this program is a type III curve. The equation used was obtained from Real (1979).

f = (KF * N^E) / (N^E + DD)

where:

f = feeding rate
KF = maximum feeding rate
N = prey density
DD = density of feed items that generate half-maximal feeding
E = exponent associated with the amount of increase in the rate of detection of a food item with an increase in food density.

The parameters used in this equation are:

KF = 110 E = 2.5 DD = 300

The points generated from these two equations at prey densities of 0 to 100 were placed in data statements to increase the speed of plotting.

Next this program covers equilibrium points and their stability, and also allows changes in predator carrying capacity. Predator carrying capacity, in this program, is equivalent to K in the equation for the type III response curve (Real, 1979). The reason is that the maximum feeding rate will change as a function of predator carrying capacity and the resulting number of predators in the system. Also, in this equation the predator carrying capacity is unrelated to the prey density. This means that the predator carrying capacity is determined by restrictions other than prey density, such as territoriality.

PRED FUNCT2 estimates the time for a prey density to equilibrate. It does this by taking the difference between the prey recruitment curve and the predator functional response curve, and subtracting this difference from the prey density to obtain the density at various time intervals.

PRED FUNCT3 demonstrates the effect of adding hunter pressure to this simple predator-prey system.

Because hunter pressure tends to take a percentage of the prey population regardless of population size, the graph of change in density as a function of prey density is a straight line. The equation for hunter pressure used was:

$$Y = (0.01 * HP * N)$$

where:

Y = the number of prey killed

N = the prey density

HP = hunter pressure expressed as a percentage of the prey density.

The variable HP can be changed by the user in the hunter pressure simulation. The effect of this is to raise or lower the prey recruitment curve.

PRED FUNCT INTRO

Line Numbers

5 - 28	REMARKS containing module name, program name, credits, and NSF grant number.
100 - 300	title and credits.
370 - 830	logistic growth curve is introduced and plotted.
840 - 1210	a question is asked regarding the graph displayed.
1220 - 1560	prey recruitment is introduced.
1570 - 1920	prey recruitment and logistic growth are plotted simultaneously.
2270 - 2340	the relationship of the predator is introduced.
2350 - 2390	the subprogram PRED FUNCT1 is run.
SUBROUTINES	
5000 - 5065	PAUSE subroutine.
5080 - 5130	press -RETURN- subroutine.
5750 - 5880	HGR block erasing subroutine.
6240 - 6481	HGR string drawing subroutine.
30600 - 31000	variable size graph drawing subroutine.
31010 - 31080	point scaling and plotting subroutine for variable size graph.

PRED FUNCT1
Line numbers

5 - 25	REMARK statements.
160 - 290	the graph is drawn and labelled.
300 - 460	the prey recruitment curve is drawn.
470 - 710	predator functional response curve is introduced.
720 - 890	predator functional response curve is plotted.
976 - 1140	positive and negative curves are discussed.
1150 - 1320	a question on the number of equilibrium points is asked.
1520 - 2285	equilibrium point #1 is used in a simulation on stability.
2286 - 2360	a question regarding other stable equilibrium points is asked.
2470 - 2830	predator carrying capacity is introduced as a parameter.
2840 - 3030	the predator carrying capacity is changed by the user.
3040 - 3250	the possibility of a different number of equilibrium points is brought up.
3260 - 3470	the predator carrying capacity is changed by the user.
3480 - 3690	the number of equilibrium points is checked.
3700 - 3910	the next section of the module is set up.
3920 - 3960	the subprogram PRED FUNCT2 is run.
SUBROUTINES	
4000 - 4070	subroutine that flashes spaces between curves.
4100 - 4310	subroutine that alternately colors and darkens spaces between two curves.
5000 - 5070	PAUSE subroutine.
5080 -5130	press -RETURN- subroutine.
5140 - 5270	HGR block erasing subrouine.
5280 - 5600	graph drawing subroutine.
5610 - 5680	point scaling and plotting subroutine.
10000 - 10330	DATA statements containing X and Y coordinates for prey recruitment and predator functional response curves.

PRED FUNCT2
Line numbers

5 - 30	REMARK statements.
160 - 500	a change in scale is introduced.
510 - 610	the prey recruitment curve is plotted.
620 - 780	predator functional response curve is plotted.
790 - 990	the concept of subtracting curves is introduced.
1000 - 1790	simulation that subtracts curves.
1800 - 2010	the simulation is repeated using a new starting prey density.
2020 - 2100	the concept of additional parameters is brought up.
2110 - 2140	the subprogram PRED FUNCT3 is run.
SUBROUTINES	
5000 - 5070	PAUSE subroutine.
5080 - 5130	press -RETURN- subroutine.
5140 - 5270	HGR block erasing subroutine.
5280 - 5600	graph drawing and labelling subroutine.
5610 - 5680	point scaling and plotting subroutine.

PRED FUNCT3
Line numbers

5 - 25	REMARK statements.
140 - 370	hunter pressure is introduced.
380 -500	prey recruitment curve is plotted.
510 - 650	hunter pressure is plotted.
660 - 780	the concept of positive and negative curves is applied.
790 - 890	the two curves are subtracted.
900 -1000	predator functional response is plotted.
1010 - 1210	a hypothetical situation is introduced.
1220 - 1490	hunter pressure is input by the user.
1500 - 1660	the prey recruitment curve is lowered to account for hunter pressure.
1670 - 1830	the user increases hunter pressure.
1840 - 2110	the loss of a stable equilibrium due to hunter pressure is demonstrated.
2120 - 2430	hunter pressure is taken away.
2440 - 2730	conclusion for the entire module.
SUBROUTINES	
4000 - 4080	PAUSE, RETURN, PAUSE, VTAB subroutine.
4100 - 4300	subroutine that erases one curve while plotting another.
4400 - 4480	subroutine that plots predator functional response.
5000 - 5130	press -RETURN- subroutine.
5140 - 5270	HGR block erasing subroutine.
5280 - 5600	graph drawing and labelling subroutine.
5610 - 5680	point scaling and plotting subroutine.

10000 - 10330 DATA statements containing X and Y coordinates for prey recruitment curve and predator functional response curve.

VARIABLE LIST

PRED FUNCT INTRO

COUNT - flag variable used to ask a question twice.
D$ - Disk Operating System variable.
D1 - change in prey population with change in time.
FLAG - flag in HGR string drawing subroutine.
K - prey carrying capacity.
L - HGR block erasing subroutine. Length along Y-axis of block to be erased.
L$ - axes labelling subroutine. Axis label.
LXA - axes drawing subroutine. Length of X-axis.
LYA - axes drawing subroutine. Length of Y-axis.
N - prey population number.
PAUSE - PAUSE subroutine. Pause length.
PS - PAUSE subroutine. Pause loop variable.
Q$ - press -RETURN- subroutine. Input variable.
R - intrinsic rate of growth of prey population.
T - loop variable representing time interval.
TA - HGR block erasing subroutine. Loop variable.
X - graphing subroutine. X coordinate.
HGR block erasing subroutine. Starting X coordinate.
X$ - axes labelling subroutine. X-axis label.
X0 - axes labelling subroutine. X-axis label starting X coordinate.
X1 - axes drawing subroutine. Starting X coordinate.
X8 - storage variable for X coordinate of previous prey recruitment point.
X9 - storage variable for X coordinate of previous logistic curve point.
XA - HGR string drawing subroutine. Starting X coordinate.
XM - graph subroutine. Maximum X value.
XZ - HGR block erasing subroutine. Width along X-axis to be erased.
Y - graphing subroutine. Y coordinate.
HGR block erasing subroutine. Starting Y coordinate.
Y$ - axes labelling subroutine. Y-axis label.
Y0 - axes labelling subroutine. Starting coordinate for Y-axis label.
Y1 - axes drawing subroutine. Starting Y coordinate.
Y8 - storage for Y coordinate of previous prey recruitment point.
Y9 - storage for Y coordinate of previous logistic curve point.
YA - HGR string drawing subroutine. Starting Y coordinate.
YM - graphing subroutine. Maximum Y value.
YM$ - graphing subroutine. Maximum Y value.
Z - HGR string drawing subroutine. Loop variable equal to the length of the string to be drawn.
Z$ - graph labelling subroutine . String to be drawn.
Z0 - graph labelling subroutine. Flag for printing horizontally or vertically.
Z3 - graph labelling subroutine. Variable equal to numbers along axes.

ZF - graphing subroutine. Flag to plot line or dot graph.
ZG - graphing subroutine. Flag to start plotting line or dot graph.
ZZ - HGR string drawing subroutine.

VARIABLE LIST

PRED FUNCT1

A - space flashing subroutine. Starting X value.
B - space flashing subroutine. Ending X value.
CA - multiple space flashing subroutine. Counter for first space to be colored.
CB - multiple space flashing subroutine. Counter for second space to be colored.
CC - multiple space flashing subroutine. Counter for third space to be colored.
CD - Multiple space flashing subroutine. Counter for fourth space to be colored.
CE - multiple space flashing subroutine. Flag used to flash all four spaces or just two.
COUNT - flag to replot predator functional response curve.
D$ - Disk Operating System variable.
DD - density of prey that generate half-maximal feeding.
E - parameter associated with the amount of increase in the rate of detection of a prey individual with an increase in food density.
H1 - multiple space flashing subroutine. HCOLOR of first space.
H2 - multiple space flashing subroutine. HCOLOR of second space.
H3 - multiple space flashing subroutine. HCOLOR of third space.
H4 - multiple space flashing subroutine. HCOLOR of fourth space.
HC - space flashing subroutine. HCOLOR of space.
I - loop variable.
KF - predator carrying capacity.
KK - temporary storage for previous predator carrying capacity.
L - HGR block erasing subroutine. Length along Y-axis of block to be erased.
L$ - axes labelling subroutine. Axis label.
LG - multiple space flashing subroutine. Loop size.
N - prey population number.
PAUSE - PAUSE subroutine. Pause length.
PS - PAUSE subroutine. Pause loop variable.
Q$ - press -RETURN- subroutine. Input variable.
R - intrinsic rate of growth of prey population.
SC - graph labelling subroutine. Scaling variable.
ST - space flashing subroutine. Loop step size.
T - loop variable representing time interval.
TA - HGR block erasing subroutine. Loop variable.
WRITE - graph labelling subroutine. Flag for text statements.
X - graphing subroutine. X coordinate.
HGR block erasing subroutine. Starting X coordinate.

X$ - axes labelling subroutine. X-axis label.
X0 - axes labelling subroutine. Sarting X coordinate of X-axis label.
X2(- X coordinates for the two curves.
XM - graphing subroutine. Maximum X value.
XZ - HGR block erasing subroutine. Width along X-axis to be erased.
Y - graphing subroutine. Y coordinate.
Y$ - axes labelling subroutine. Y-axis label.
Y0 - axes labelling subroutine. Starting coordinate for Y-axis label.
Y1(- Y coordinates for prey recruitment curve.
Y2(- Y coordinates for predator functional response curve.
YE - equilibrium point #3.
YM - graphing subroutine. Maximum Y value.
YS - equilibrium point #1.
YU - equilibrium point #2.
Z - HGR string drawing subroutine. Loop variable equal to the length of the string to be drawn.
Z0 - graph labelling subroutine. Flag for printing horizontally or vertically.
Z3 - graph labelling subroutine. Variable equal to numbers along axes.
ZF - graph subroutine. Flag to plot line or dot graph.
ZG - graphing subroutine. Flag to start plotting line or dot graph.

VARIABLE LIST
PRED FUNCT2
COUNT - counter of time intervals to reach equilibrium.
CT - flag to skip mandatory input of new starting prey density.
D$ - Disk Operating System variable.
DD - density of prey that generate half-maximal feeding.
E - parameter associated with the amount of increase in the rate of detection of a food item with an increase in food density.
H - Loop variable.
I - loop variable.
J - storage for previous I value.
KF - predator carrying capacity.
L - HGR block erasing subroutine. Length along Y-axis of block to be erased.
L$ - axes labelling subroutine. Axis label.
PAUSE - PAUSE subroutine. Pause length.
PS - PAUSE subroutine. Pause loop variable.
Q$ - press -RETURN- subroutine. Input variable.
R - intrinsic rate of growth of prey population.
SC - graph labelling subroutine. Scaling variable.
TA - HGR block erasing subroutine. Loop variable.
TP - temporary storage of previous Y coordinate of predator functional response curve poiht.
X - graphing subroutine. X coordinate.

X$ - axes labelling subroutine. X-axis label.
XO - axes labelling subroutine. Starting X coordinate for X-axis label.
X2(- X coordinates for the two curves.
XM - graphing subroutine. Maximum X value.
XX - storage of difference between the two curves, subtracted from the X-axis.
XZ - HGR block erasing subroutine. Width along X-axis to be erased.
Y - graphing subroutine. Y coordinate.
HGR block erasing subroutine. Starting Y coordinate.
Y$ - axes labelling subroutine. Y-axis label.
YO - axes labelling subroutine. Startine coordinate for Y-axis label.
Y1(- Y coordinates for prey recruitment curve.
Y2(- Y coordinates for predator functional response curve.
YE - equilibrium point #3.
YM - graphing subroutine. Maximum Y value.
YS - equilibrium point #1.
YU - equilibrium point #2
Z - HGR string drawing subroutine. Loop variable equal to the length of the string to be drawn.
ZO - graph labelling subroutine. Flag for printing horizontally or vertically.
Z3 - graph labelling subroutine. Variable equal to numbers along axes.
ZF - graphing subroutine. Flag to plot line or dot graph.
ZG - graphing subroutine. Flag to start plotting line or dot graph.

VARIABLE LIST
PRED FUNCT3
FLAG - curve erasing, curve plotting subroutine. Flag to erase hunter pressure line.
HC - curve erasing, curve plotting subroutine. HCOLOR of to be plotted.
HO - storage variable for previous hunter pressure.
HP - hunter pressure as a percentage of prey density.
HTEMP - storage for hunter pressure.
I - loop variable.
L - HGR block erasing subroutine. Length along Y-axis of block to be erased.
L$ - axes labelling subroutine. Axis label.
N - prey population number.
PAUSE - PAUSE subroutine. Pause length.
PS - PAUSE subroutine. Pause loop variable.
Q$ - press -RETURN- subroutine. Input variable.
SC - graph labelling subroutine. Scaling variable.
TA - HGR block erasing subroutine. Loop variable.
WRITE - graph labelling subroutine. Flag text statements.
X - graphing subroutine. X coordinate.
X$ - axes labelling subroutine. X-axis label.
XO - axes labelling subroutine. X-axis label starting X coordinate.

X2(- X coordinates for the two curves.
X7 - storage variable for previous recruitment curve minus HP X coordinate.
X8 - storage variable for previous HP X coordinate.
X9 - storage variable for previous recruitment curve X coordinate.
Y - graphing subroutine. Y coordinate.
Y$ - axes labelling subroutine. Y-axis label.
Y0 - axes labelling subroutine. Starting coordinate for Y-axis label.
Y1(- Y coordinates for prey recruitment curve.
Y2(- Y coordinates for predator functional response curve.
Y7 - storage variable for previous recruitment curve minus HP Y coordinate.
Y8 - storage variable for previous HP Y coordinate.
Y9 - storage variable for previous recruitment curve Y coordinate.
Z - HGR string drawing subroutine. Loop variable equal to the length of the string to be drawn.
Z0 - graph labelling subroutine. Flag for printing horizontally or vertically.
Z3 - graph labelling subroutine. Variable equal to numbers along axes.
ZF - graphing subroutine. Flag to plot line or dot graph.
ZG - graphing subroutine. Flag to start plotting line or dot graph.

APPENDIX B

Predator Functional Response
Module Performance Objectives

Following is a list of the 19 performance objectives developed for the PFR module. The numbers in parentheses preceding each objective refer to the posttest items that test for that particular objective.

PFR Performance Objectives

After running the PFR module the student should be able to:

(1) recognize the definition of prey recruitment.

(2) correlate predator functional response with prey losses.

(3) predict the effect of different predator carrying capacities.

(4) identify by recognition the shape of a hunter pressure curve.

(5) predict the shape of the prey recruitment curve, given the prey growth curve.

(18) identify equilibrium points on a prey recruitment-predator functional response graph.

(6,7) identify the stability of equilibrium points on a prey recruitment-predator functional response graph.

(8,9) predict the direction that a chosen prey density will go to approach equilibrium.

(8) predict the time interval involved for a chosen prey to approach equilibrium.

(9) predict the changes in the system due to a change in the number of predators.

(10) identify equivalent points on a prey growth curve and a prey recruitment curve.

(11) predict which point on the prey recruitment curve represents prey carrying capacity.

(12) identify the point of maximum prey growth on the prey recruitment curve.

(13) recognize the definition of a stable equilibrium point.

(14) recognize the effect of hunter pressure.

(15) recognize the definition of predator functional response.

(16) identify the curve that is affected by satiation.

(17,20) identify the reasons for the shape of the predator functional response curve.

(19) recognize how hunter pressure affects prey recruitment.

APPENDIX C

Predator Functional Response Posttest

Following is a copy of the posttest used in the PFR module vs. lecture comparison. For the correct responses, please refer to page C8. Appendix B contains the list of performance objectives which this posttest tested for.

Predator Functional Response post test

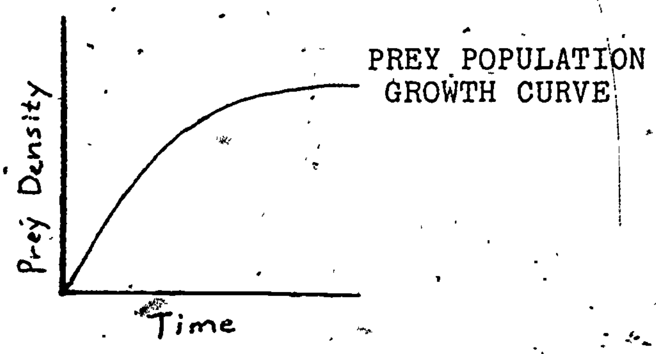
1. Which of the following best describes prey recruitment?
Prey births minus:
   a) prey deaths as a function of time.
   b) prey deaths as a function of prey density.
   c) nonpredator related deaths as a function of time.
   d) nonpredator related deaths as a function of prey density.
   e) predator related deaths as a function of prey density.

2. Which one of the following curves represents subtractions from the prey population?
   a) prey recruitment curve.
   b) predator functional response curve.
   c) predator numerical response curve.
   d) prey growth curve.
   e) none of the above.

3. Which of the following would result in the predator functional response curve leveling off at a higher level?
   a) a decrease in the number of hunters.
   b) a decrease in the number of prey.
   c) an increase in predator carrying capacity.
   d) an increase in the number of hunters.
   e) an increase in the number of prey.

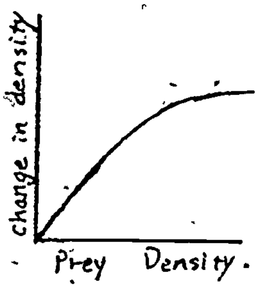
4. Studies have shown that the shape of a hunter pressure curve tends to be
   a) sigmoid.
   b) hyperbolic.
   c) logistic.
   d) exponential.
   e) linear.

Item 5 pertains to the following graph.

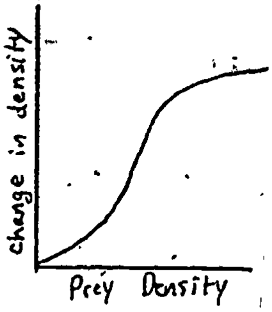


5. Which one of the following prey recruitment curves corresponds to the given prey population growth curve?

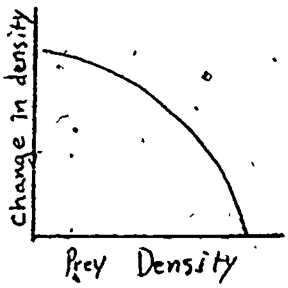
a)



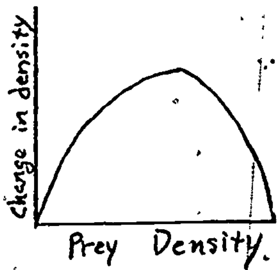
b)



c)



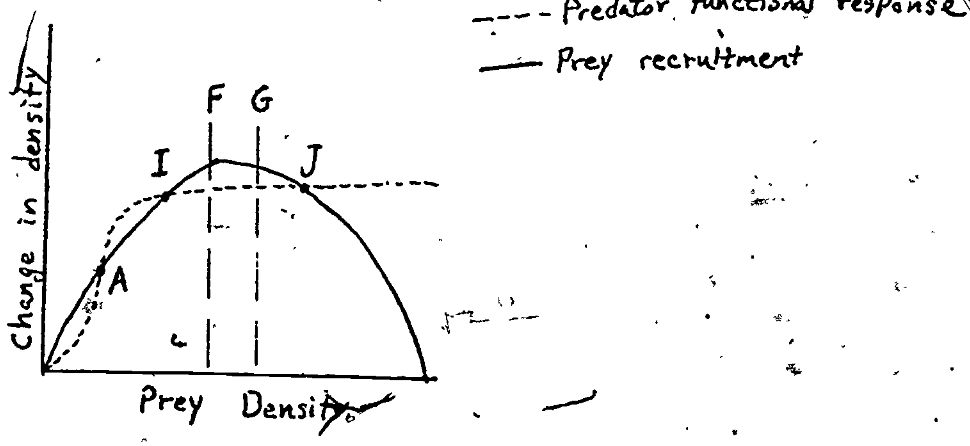
d).



e) None of the above.

6. When only one equilibrium point exists in a prey recruitment-predator functional response graph, that equilibrium point is.
   a) neutral.
   b) transitory.
   c) stable.
   d) unstable.
   e) none of the above.

Items 7 - 9 pertain to the following graph.

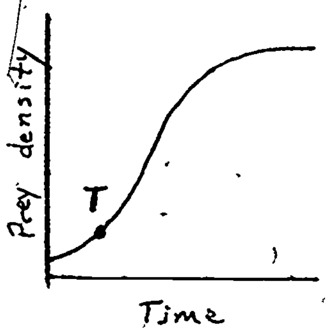


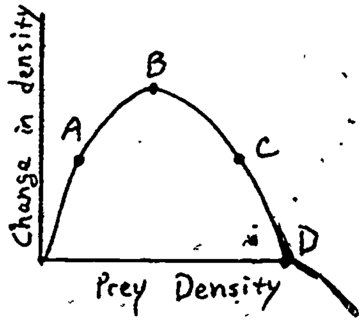
7. Point A is
   a) stable.
   b) unstable.
   c) neutral.
   d) transitory.
   e) none of the above.

8. If the prey density of an area is starting at point F, it would approach a stable equilibrium point in a
   a) shorter time than a prey density starting at point G.
   b) longer time than a prey density starting at point G.
   c) time interval about equal to that which a prey density starting at point G would.
   d) time that cannot be compared to that of the prey density starting at point G.

9. If the prey density is at equilibrium point J, what would be the result of removal of all predators?
   The prey density would:
   a) decrease to a lower stable equilibrium point.
   b) decrease to an unstable equilibrium point.
   c) stay at point J because it is a stable equilibrium.
   d) increase greatly due to lack of predators.
   e) increase slightly to the prey carrying capacity.

Note: Use the following graph for questions # 10, 11, and 12.





10. Point T on the prey growth curve is equivalent to which point on the prey recruitment curve?
    a) A
    b) B
    c) C
    d) D
    e) The two curves are not related.

11. Which point on the given prey recruitment curve represents growth at the prey carrying capacity?
    a) A
    b) B
    c) C
    d) D
    e) Cannot be determined from the prey recruitment curve.

12. Which point on the above prey recruitment curve most closely represents maximum prey population growth rate?
    a) A
    b) B
    c) C
    d) D
    e) Cannot be determined from the prey recruitment curve.

13. An equilibrium point is said to be stable when the prey density will

a) NOT move from that point.
b) change at a single, stable rate.
c) tend to move away from that point when disturbed.
d) tend to move toward a neutral point when disturbed.
e) tend to return to that point when disturbed.

14. Increasing hunter pressure has the effect of

a) lowering the predator functional response curve.
b) lowering the prey recruitment curve.
c) raising the predator functional response curve.
d) raising the prey recruitment curve.
e) none of the above.

15. The predator functional response curve represents the growth of

a) the predator population.
b) an individual predator.
c) the prey population.
d) hunter pressure.
e) none of the above.

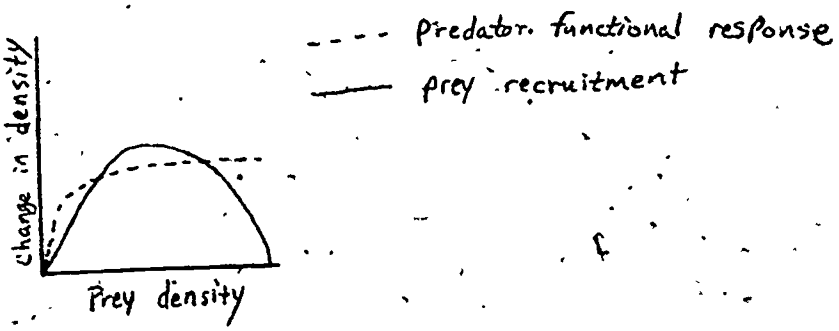
16. Satiation affects which of the following?

a) the predator functional response curve.
b) the prey recruitment curve.
c) the prey growth curve.
d) the predator population growth curve.
e) none of the above.

17. The predator functional response curve levels off because

a) the prey population can grow no larger.
b) the predator population can grow no larger.
c) the prey response is limited.
d) the predator can eat only so many prey.
e) none of the above.

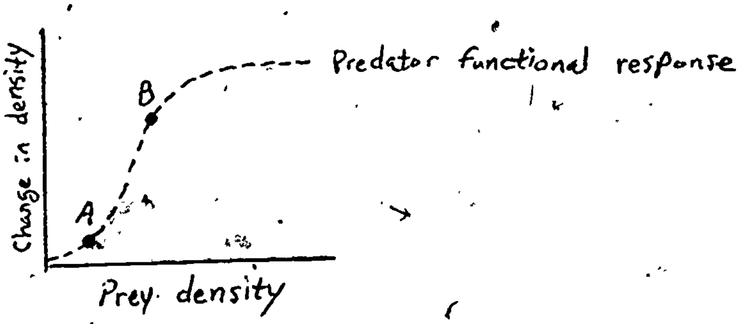
Item 18 pertains to the following graph.



18. On the above graph, how many equilibrium points are there in this predator-prey system?
   a) 1
   b) 2
   c) 3
   d) 4
   e) more than 4.

19. To account for hunter pressure;
   a) divide hunter pressure by prey recruitment.
   b) divide prey recruitment by hunter pressure.
   c) add prey recruitment to hunter pressure.
   d) subtract prey recruitment from hunter pressure
   e) none of the above.

Item 20 pertains to the following graph.



20. The predator functional response curve rises rapidly between point A and point B because
   a) there is a rapid increase in prey density.
   b) there is a rapid increase in predator density.
   c) the predators switch to the prey studied.
   d) the predators switch away from the prey studied.
   e) none of the above.

PFR post test KEY

1. d
2. b
3. c
4. e
5. c
6. c
7. a
8. b
9. e
10. a
11. d
12. b
13. e
14. b
15. e
16. a
17. d
18. b
19. e
20. c

APPENDIX D

Random Division Program

Following is a copy of the Apple microcomputer program that was used to randomly divide the BL340 Animal Ecology students into two groups. It worked by associating each student's name with a random number between zero and one, then ranking these numbers from lowest to highest. By a flip of a coin it was decided that students associated with the lowest 15 random numbers were to be the module group, and the remaining students would make up the lecture group.

```
50  REM  RANDOM DIVISION
60  REM  THIS PROGRAM IS DESIGNED TO DIVIDE THE BL340
     CLASS INTO HALF RANDOMLY.
100  DIM ST$(30),NUMBER(30)
105  HOME
110  FOR I = 1 TO 30
120  READ ST$(I)
130 NUMBER(I) =  RND (I)
140  NEXT
150  FOR I = 1 TO 29
160  FOR J = I + 1 TO 30
170  IF NUMBER(I) < NUMBER(J) GOTO 240
180 X$ = ST$(I)
190 Y = NUMBER(I)
200 ST$(I) = ST$(J)
210 NUMBER(I) = NUMBER(J)
220 ST$(J) = X$
230 NUMBER(J) = Y
240  NEXT
250  NEXT
251  PRINT "THESE STUDENTS WILL REPORT TO           RO
     OM 1105 ON WEDNESDAY AT 11 A.M."
252  PRINT : PRINT
255  PRINT
257  PRINT
260  FOR I = 1 TO 30
275  IF I = 16 THEN  PRINT : PRINT : PRINT "----------
     ------------------------------": PRINT : PRINT : PRINT
     "THESE STUDENTS WILL REPORT TO           ROOM 406
      ON WEDNESDAY AT 11 A.M.": PRINT : PRINT
277  PRINT ST$(I)
280  NEXT
300  DATA ATMA,BARNEY,BROOKS,DALE,DEMEUSE,HOAG,HOLMES,
     HUNT
310  DATA HUTCHINGS,KINDBERG,LEDBETTER,LIDGARD,LINSE,L
     INTON,MALCHOW,MEALEY
320  DATA MOEHRING,NOTH,ONEILL,RICHARDS,ROSICK,SANCH,T
     APANINEN,TREMAINE
330  DATA VAUGHT,WHITMIRE,WIARD,WILSON,WRIGHT,ZETYE
340  REM
```

THESE STUDENTS WILL REPORT TO ROOM 1105 ON WEDNESDAY AT 11 A.M.

BROOKS
HUNT
DEMEUSE
SANCH
LINSE
HEALEY
NOTH
ZETYE
MALCHOW
WHITMIRE
LINTON
RICHARDS
ROSICK
TAPANINEN
MOEHRING

THESE STUDENTS WILL REPORT TO ROOM 406 ON WEDNESDAY AT 11 A.M.

KINDBERG
ONEILL
WILSON
HOLMES
WRIGHT
ATMA
LIDGARD
BARNEY
LEDBETTER
TREMAINE
HOAG
DALE
WIARD
VAUGHT
HUTCHINGS

This is the official division that was used.

APPENDIX E

Lecture Written Transcipt

Following is a written transcript of the lecture given to the Animal Ecology lecture group. This was made from a videotape of the lecture, which is available upon request.

Predator Functional Response
Lecture Transcript

(NOTE: Begin with roll call.)

Wow, only three people skipped out.

What I've got to do today is talk to you about my research for the past few months. We're doing a test, as you know, where half the class is looking at functional response disks, or modules, upstairs, and the other half of the class is you lucky people who get to listen to me talk for approximately 40 to 45 minutes, I don't know. I'll talk until about 20 to or someplace in there and then try and get some questions in; and then the rest of the class is going to come down here, and you all are going to take a posttest. It will be timed from quarter to until noon, right on. You should get done in plenty of time, though.

OK, my topic today is predator functional response and its relationships to prey recruitment, and since many people haven't heard of either one of those things, I have to start from the beginning. First I'd like to start by talking about a prey population growth curve. You've all seen prey population growth curves, but I thought I'd draw one out for you anyway, just to give you a good start on my fantastic drawings.

(NOTE: Overhead #1 of a logistic growth curve is shown.)

This is a prey population growth curve. As you can see at the beginning here it starts out with exponential growth of the population. (NOTE: The first part of the curve is pointed to.) And at the top it levels off because environmental carrying capacity takes over. (NOTE: The part of the curve that levels off is pointed to.)

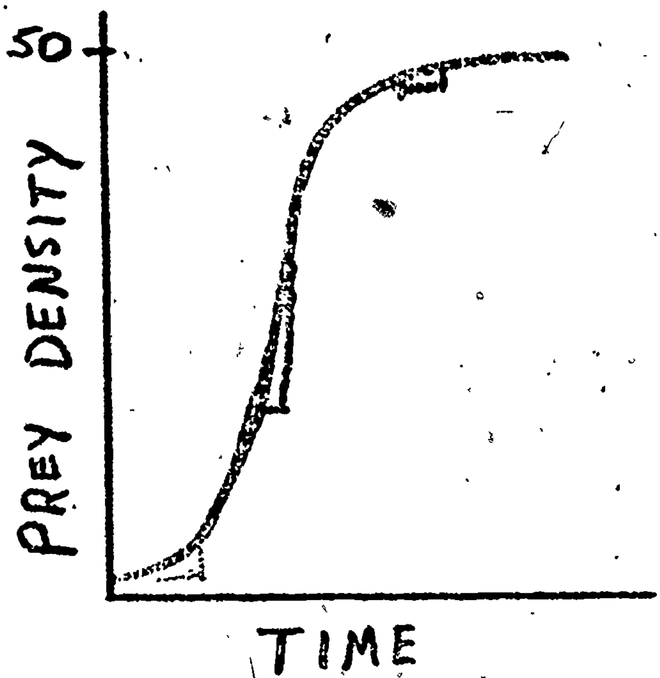
Now, if you look at this curve, can anyone tell where the population growth is the highest? And that means where the most prey are added to the population. At what prey density would that be at? Yell out something.

(NOTE: Several students respond with the correct answer.)

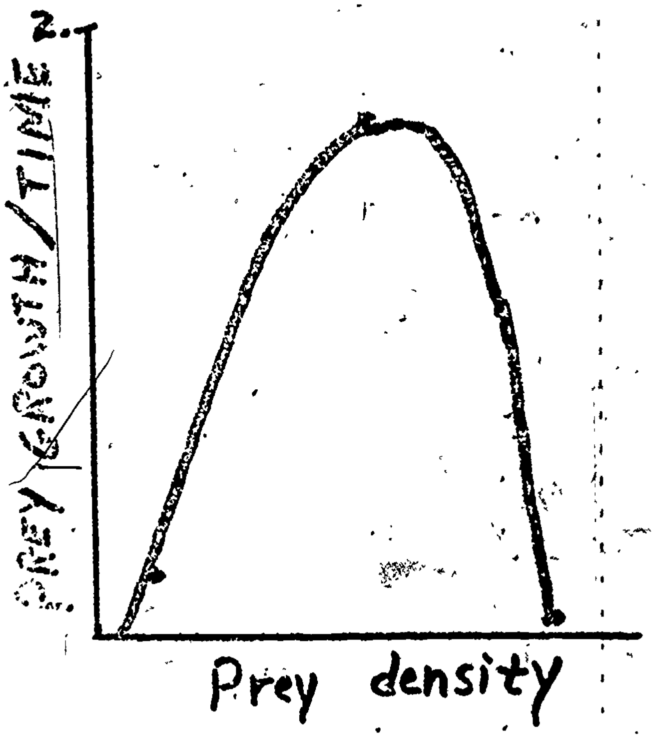
OK, alot of people might not notice that, but where the slope is the steepest, that's where the prey population growth is the highest. Sometimes it's a hard concept to catch, so some fantastic person came up with the idea of a prey recruitment curve (NOTE: The prey recruitment curve axes on overhead #1 are revealed) where they graph prey density as the independent variable along the bottom (NOTE: The x-axis is pointed to) and along the side they put prey growth per time, which is the number of prey added per a unit of time.

I'll show you how these prey recruitment curves come about. If you start at a low prey density, say here (NOTE: a point of low prey density was pointed to on the prey population growth curve) and you went for one unit time, and say one unit time is half an inch along this axis; if

PREY POPULATION GROWTH CURVE



PREY RECRUITMENT CURVE



PREY RECRUITMENT

All prey births minus nonpredator related deaths per unit time.

OVERHEAD #1

you went across, then up, you're only going up a little bit, (NOTE: This is drawn on the overhead with a marker) like so. Hope that looks OK. My hand's a little shakey today, excuse me.

So that means at low prey density the prey growth per time is also low, so the point would be somewhere in there (NOTE: The corresponding point is plotted on the prey recruitment curve) on your prey recruitment curve.

Now if you went into where the prey growth is really high, like in here somewhere (NOTE: The steep part of the prey population growth curve is pointed to), you're going to go up a long ways (NOTE: Lines over one time unit, then up to the curve are drawn).

So if you go to a medium prey density here (NOTE: medium prey density on the prey recruitment curve is pointed to) it's going to be very high growth, so we'll put a point right here (NOTE: this point is plotted on the prey recruitment curve).

And then if you go up by the carrying capacity and do the same thing you'll have very low growth again (NOTE: this point is plotted on the prey recruitment axes).

The whole effect is that a prey recruitment curve is shaped something like this. (NOTE: a prey recruitment curve is drawn using the axes and plotted points on the overhead.) OK?

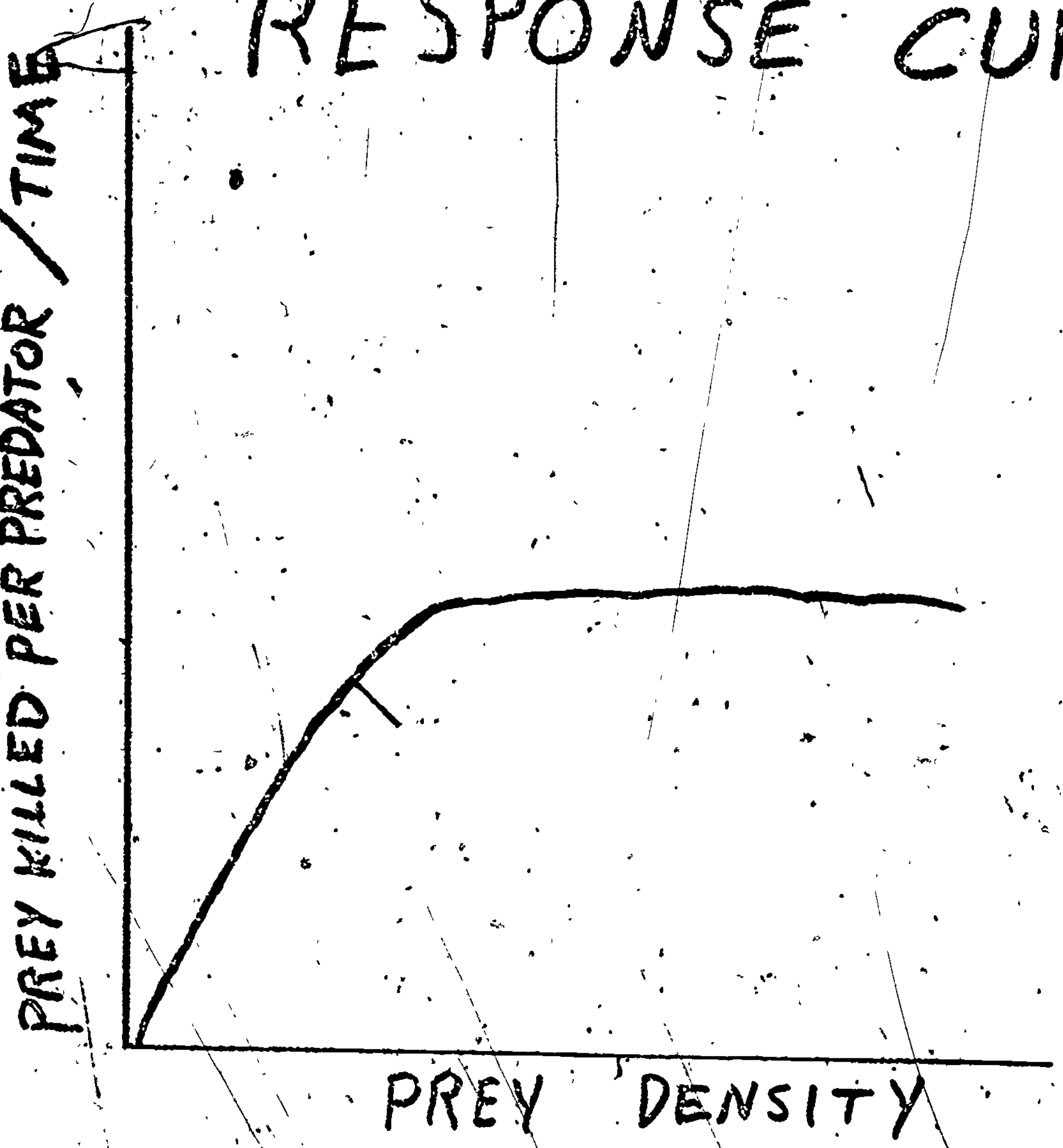
Not bad, I hit every point. This is a prey recruitment curve. What we're talking about is that, I forgot to tell you, this prey population growth curve is in the absence of predators at this time. So this prey recruitment curve is also calculated with no predators around. This is how they'd grow if there were no predators in the area.

With this in mind we could define prey recruitment as all prey births minus nonpredator related deaths per unit time.

That makes sense because the prey recruitment is the number of prey added to the population at different prey densities. If you're taking all the prey births per unit time at that prey density and subtracting all the nonpredator related deaths, then you'll come up with the net gain at different prey densities.

So now you know what a prey recruitment curve is. Next we go to the predators and start looking at them. You've all seen predator numerical response. That's when the predators respond to a change in prey density by changing their numbers. Like with the lynx-hare populations, when the hare population goes really high, the lynx population starts to follow it. That's predator numerical response. For today we're interested in predator functional response. What that is is the change in predator behavior in response to prey density. Predator functional response is graphed on these axes (NOTE: overhead #2 is displayed - PFR axes with PFR definition written below). These are the axes that predator functional response is usually graphed on.

PREDATOR FUNCTIONAL RESPONSE CURVE



PREDATOR FUNCTIONAL RESPONSE

A change in predator behavior in response to prey density

OVERHEAD #2

It is the prey killed per predator, this is for a SINGLE predator, per unit of time, and it's as a function of prey density.

I said that predator functional response is a change in predator behavior in response to prey density. That predator behavior is the number of prey that predator eats.

To draw out a general shape of a predator functional response curve, what you do is think about it for a minute.

At really low prey densities the predator's got to live, so he has to kill nearly every prey he runs in to because he's got to survive. So the curve is going to be generally increasing at first (NOTE: this was plotted on the axes on the overhead) and then once you get up a little ways in the prey density the predator can only eat so much. Like, if he can only eat five prey it doesn't matter if there are five prey per acre or 50 prey per acre. He's only going to kill five and eat them. So the curve levels off at higher prey densities. (NOTE: This section of the PFR curve is plotted on the overhead.)

That's generally the shape of a predator functional response curve. It's constantly increasing until it hits where predators are satiated. That's the term; predator satiation. Then the curve levels off.

This curve is for a single predator. If you had a study area, like Isle Royale for example, where you had 10 wolves instead of one wolf. Instead of a single predator you had multiple predators, a bunch of them. And you still wanted to see the predator functional response curve for this. You can so that, too. Next I'll show you an example of that. I'll draw that on the board.

We use about the same axes. You have prey density along the bottom again. (NOTE: axes are drawn on the blackboard. The X-axis is labelled "prey density".) The only difference in the axes is that this (NOTE: the Y-axis is pointed at) is prey killed by a fixed number of predators, say 10 wolves, instead of a single predator. That's the difference in this. Plus we're going to make an assumption to show you a different kind of predator functional response curve. We'll make the assumption that these predators have an alternate food source so that when prey density is really low they can live on something else.

(NOTE: a student walks in late.)

So at low prey densities the predator is living on something else, so they don't have to worry about this prey at all, In fact, they don't even go searching for them or anything. So the curve doesn't go up very quickly, just slow and easy. (NOTE: the low prey density section of the curve is drawn on the blackboard.)

But at a certain prey density the predators start to notice these prey and they say, "These look good." They learn how to hunt them and they learn that they taste good and everything. So they sort of learn how to kill these prey and how to eat them and hunt them. So the curve goes

up very rapidly at a very small increase in prey density. (NOTE: the mid-prey density section of the curve is plotted on the blackboard.)

(NOTE: a second student walks in late.)

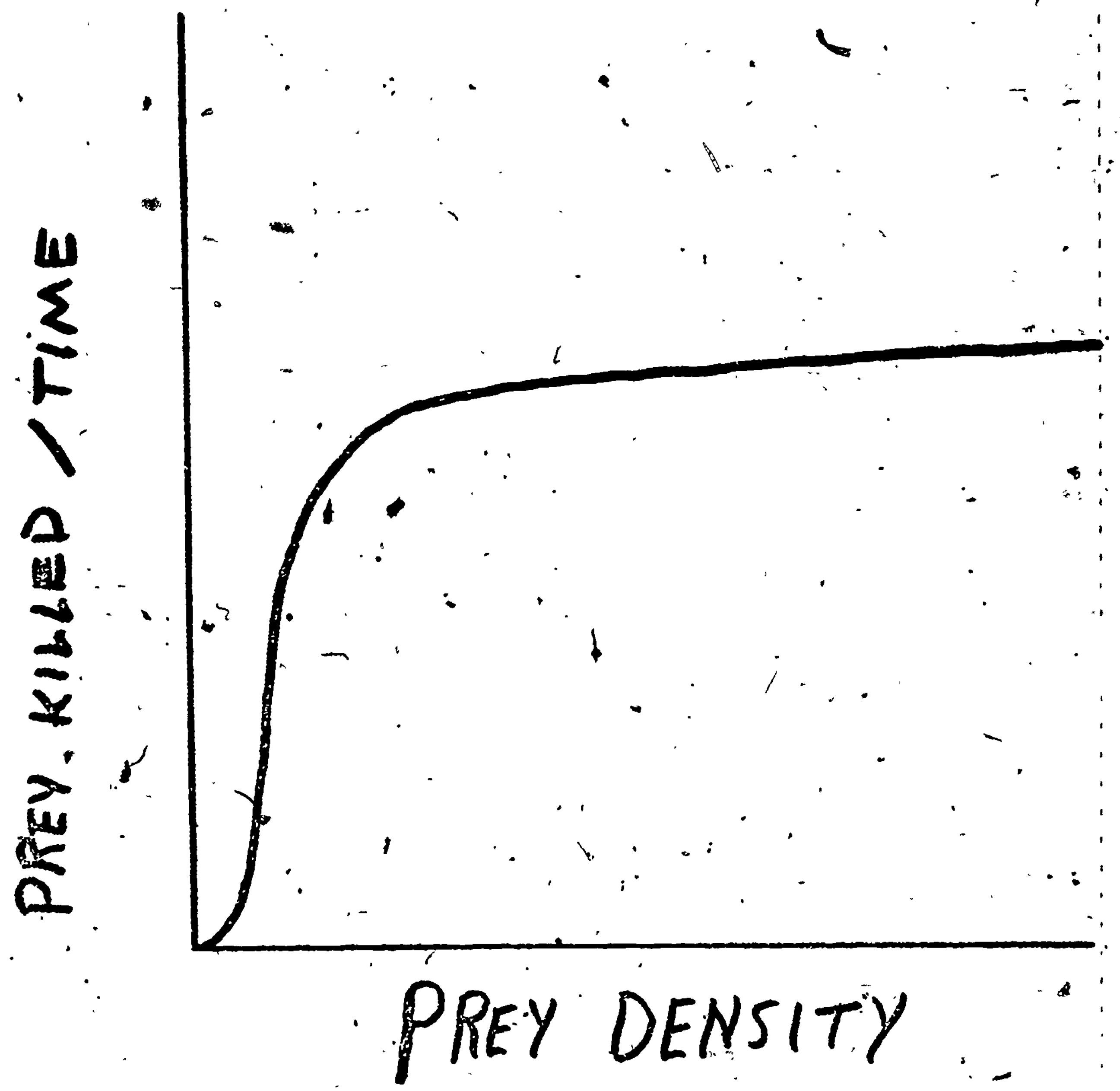
At the top, again predator satiation comes into effect, so the curve levels off, like that. (NOTE: the rest of the PFR curve is drawn on the blackboard.)

This is another type of predator functional response curve, and this is for a fixed number of predators. I drew a neater example of this on the overhead. (NOTE: overhead #3 is displayed.) Here's the same type of thing. Now if we study the predator and the prey for this area, we can put the prey recruitment curve on about the same graph and look at some relationships. (NOTE: overlay overhead #4 on #3.) This is with prey recruitment and predator functional response on the same graph. Notice the Y-axis for the blue line, which is the prey recruitment curve, is prey growth per time, which is prey added to the population. The red line, the predator functional response curve, is prey killed per time, or prey subtracted from the prey density per unit time.

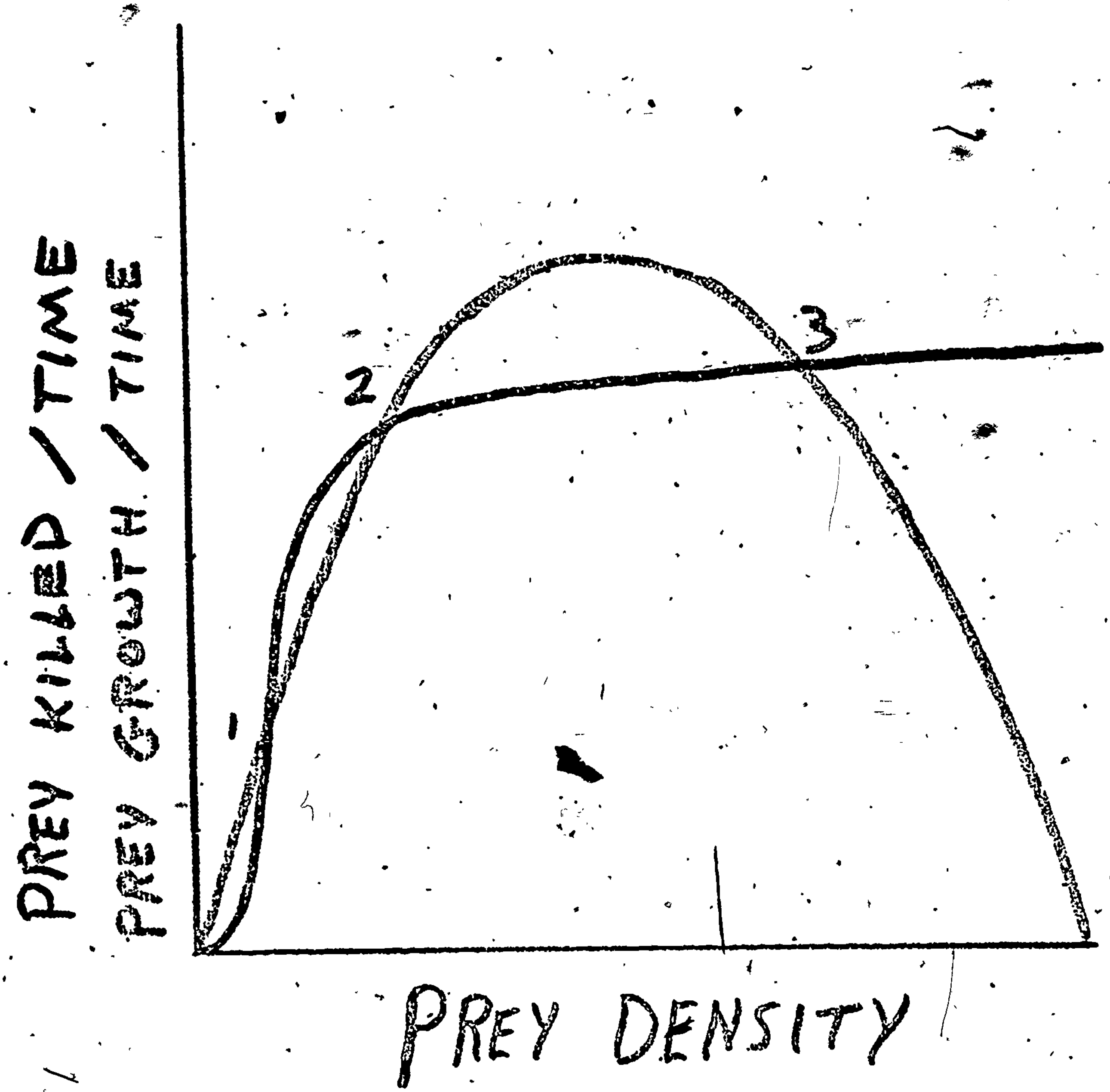
If you look at this as a positive line (NOTE: the prey recruitment curve is pointed at) and a negative line (NOTE: the PFR curve is pointed at), you can find some relationships in the curves. I'd like to talk to you about some of them.

The first one I'd like to talk about are equilibrium points. Equilibrium points are when the prey additions to the population and prey subtractions are equal. So the prey density will stay at one point; it will not change. We have equilibrium points wherever the two curves intersect. I'll number these. (NOTE: the three equilibrium points on the overheads were numbered.) We have three equilibrium points in this predator-prey relationship. If the prey density is at any of these three equilibrium points, it's not going to move away from that equilibrium point. It will tend to stay there. At least if something doesn't come along and screw it up.

Next I'd like to talk about stability of equilibrium points. For that I'll use equilibrium point number one as an example. If prey density is right on that point, that means prey additions and prey subtractions from the population are equal; so it's going to stay right there. But if the prey density is a little bit below equilibrium point number one, then you'll see that the blue line, which is additions to the population, is higher than subtractions from the population, or the functional response curve. So if additions to the population are higher than subtractions from it, then you can expect the prey density to move up because you're adding to the population and the prey density. If the prey density is in this area, it's going to move up to equilibrium point number one and then stop. If the prey density was above equilibrium point number one, in



OVERHEAD #3



OVERHEAD #4 overlaying #3

this area right here (NOTE: the area of the graph between equilibrium points #1 and 2 is pointed to), then you can see that the functional response curve is higher. That means that subtractions from the population are higher than additions. So the prey density is going to move down. So if the prey density is in this area, it is going to tend to move down to equilibrium point number one.

So if the prey density is in the area of equilibrium point number one, it is going to tend to move to that point. If it moves to that point, that means we call equilibrium point number one stable.

If equilibrium point number one is stable, then by the same reasoning equilibrium point number three is also stable, because if the prey density is anywhere in that area, it will tend to move toward equilibrium point number three. And equilibrium point number two is unstable by the same reasoning because if anything is in that area it will move toward one or three, not towards two. So that's what stability means for these points.

Another thing we can look at is how quickly prey density moves to the equilibrium point, or the stable point. I guess I'll do that on the board. (NOTE: the graphs for prey recruitment and type III PFR are drawn on the blackboard.)

This is our prey recruitment-predator functional response curves. A little messy, but...

If we're at any prey density you can figure out which way the prey density is going to move and how fast it's going to move.

(NOTE: a third student arrives late.)

So let's just pick a prey density, say right there. (NOTE: a prey density was chosen on the blackboard graph.)

We want to see which way it's going to move first. Is it going to go up or is it going to go down? If we're there, then we're there, then we're here on the curves. Since this is the prey recruitment curve on top, that means additions are more than subtractions again. So the prey density is going to tend to increase.

We know the direction. Now we're wondering how fast it's going to move to the stable equilibrium point number three. To do that you have to reason this out a little bit. You think about it, and you say that this difference between prey recruitment and predator functional response is the change in prey density in a unit of time. This is how much prey density is going to be added in a unit of time. If this is prey density (NOTE: the X-axis, prey density, was pointed to) then all you have to do is add it to the prey density, the X-axis, to figure out where you'll be for your next unit of time. So if we just take this section and lay it on its side, we'll see where we'll be for the next unit of time. (NOTE: this is drawn on the blackboard.) And if we keep doing that, laying this one over, and again, and keep going until you get to the stable

equilibrium point, you get a general idea of how long it's going to take for the prey to get from here (NOTE: the original starting prey density) to the stable equilibrium point. You can do that using any prey density and compare. Like if you were here (NOTE: another starting prey density is pointed to) you could figure it out how long it would take to go that way. That's what I wanted to show you with that.

The next thing I've got to talk about is the effect of predator carrying capacity on this whole system. If we have a fixed number of predators in an area -- that's what we're studying right now with these curves -- and some environmental change occurs that allows more predators to live in that area, so we'll still be studying a fixed number of predators, but the number will be higher than before. What that does is move this curve up farther because more predators can eat more prey and so the subtractions from the prey density are going to be more.

I have an example of that. (NOTE: overhead #5 is displayed.) Here is a rather radical example of that. Again the red curve is the predator functional response curve and if you increase the predator carrying capacity quite a ways then the curve is going to go up so high that you're going to lose your two equilibrium points that were right down there. Can anyone tell me if that's a stable or unstable equilibrium point?

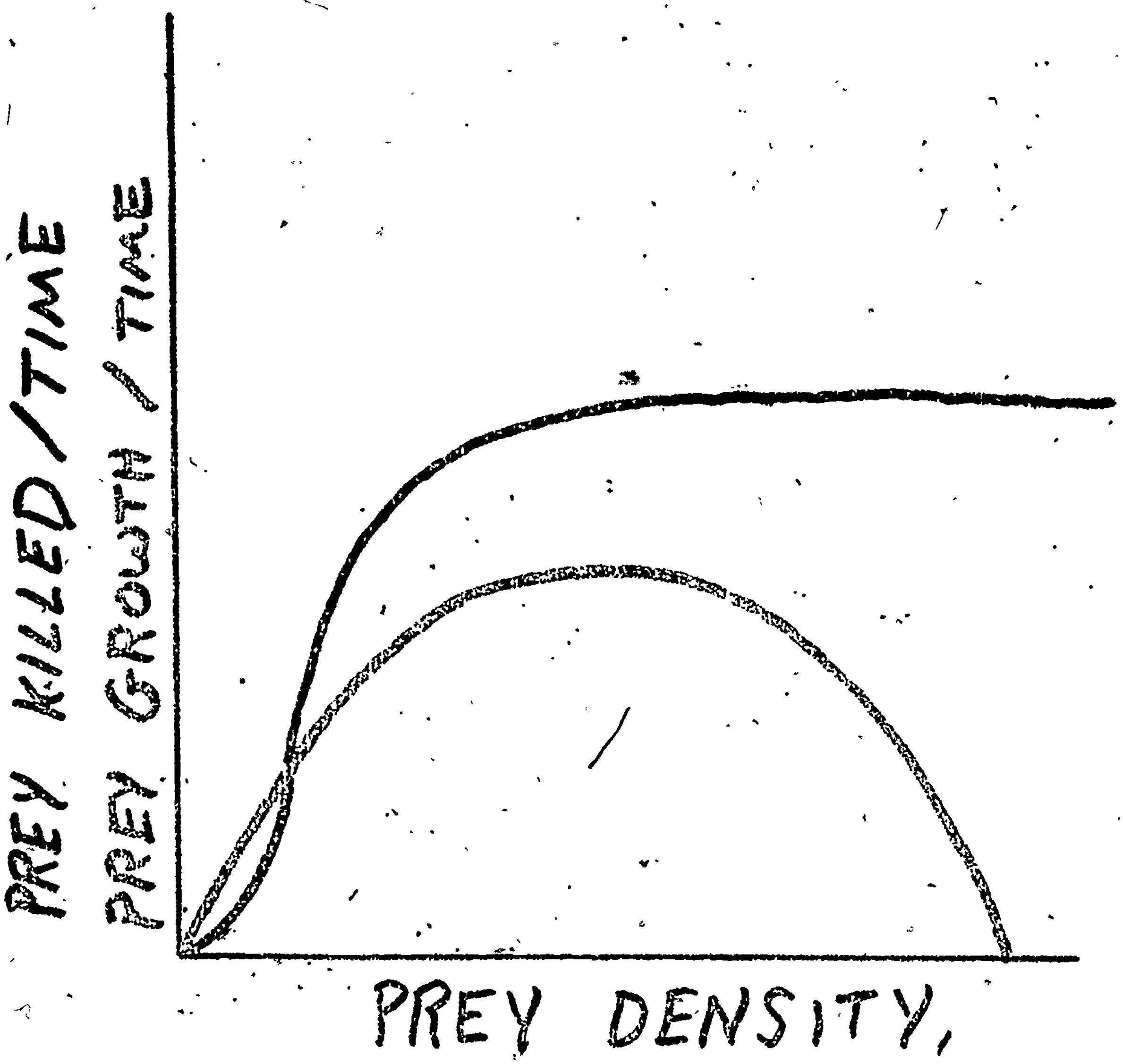
(NOTE: several students volunteer the correct response.)

Very good! It's stable because down here the prey recruitment curve is higher than the predator functional response curve, so additions are higher, so it's going to move up towards the point if it's down in this area. And if it's up in here, anywhere up in here, the predator functional response curve is higher. That means subtractions are higher than additions and so the prey density is going to move down until it hits that point. (NOTE: the equilibrium point is pointed to.)

So that equilibrium point is stable. That's pretty much what I wanted to talk about for carrying capacity.

There's another parameter... This is a pretty simple, and theoretical system. There are alot of things you could add to it. One of the things I've studied is the addition of human hunting pressure on the whole system and seeing what happens.

I'll do this on the board. If we have a prey recruitment curve for an area (NOTE: a prey recruitment curve is drawn on the blackboard) and we want to model in human hunting pressure on the prey; studies have been made on this and they've found that human hunting pressure pretty much is a linear function of prey density. If we wanted to graph human hunting pressure, say 2% of the prey population, we'd come up with something like this (NOTE: a straight line graph is drawn over the prey recruitment



OVERHEAD #5

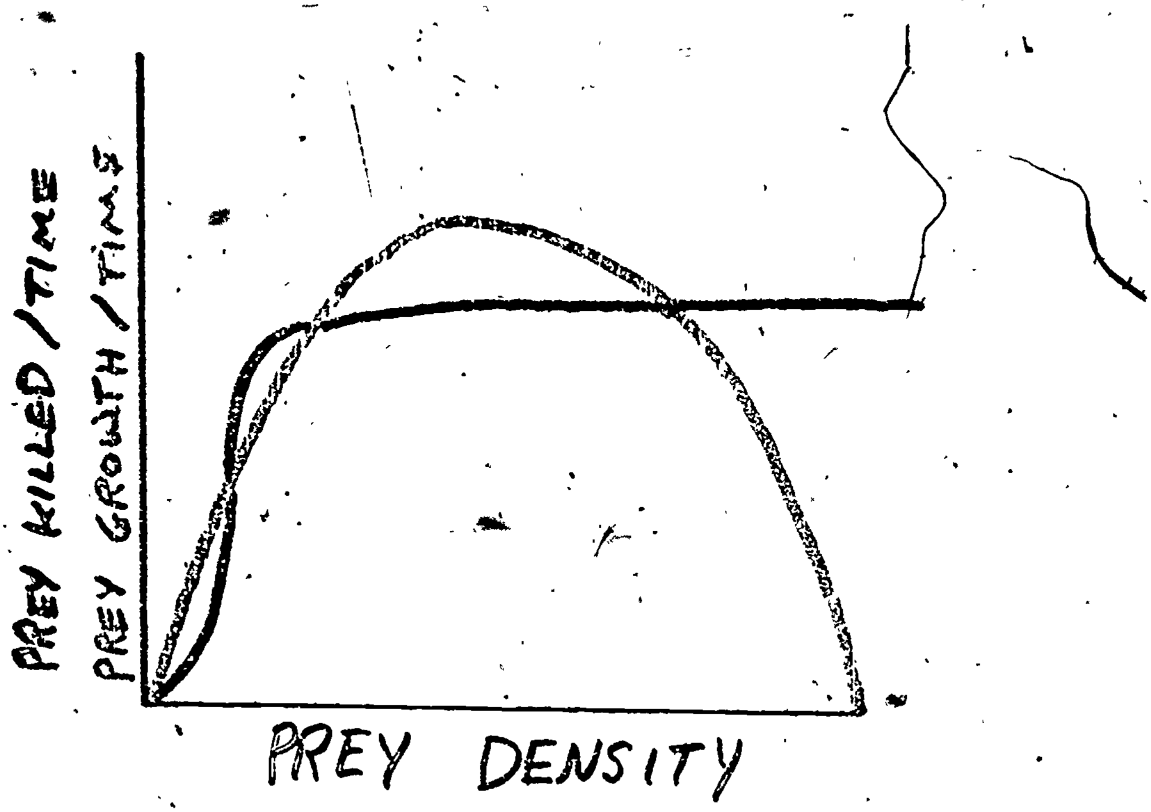
curve). Now, the prey recruitment curve, if it's prey births minus nonpredator related deaths, and we say that the human harvest are nonpredator related deaths, that means that this subtraction could be taken out from up here, and the whole prey recruitment curve would be moved down a little bit. We'd have a new prey recruitment curve that takes into account hunting pressure. So if we take a few points for example... This whole curve would just move down, and we'd have a new prey recruitment curve that took into account hunter pressure. While all of this is going on the predator functional response curve is completely unrelated to hunter pressure, so that thing is unchanged no matter what. (NOTE: a type III predator functional response curve is drawn over the new prey recruitment curve.)

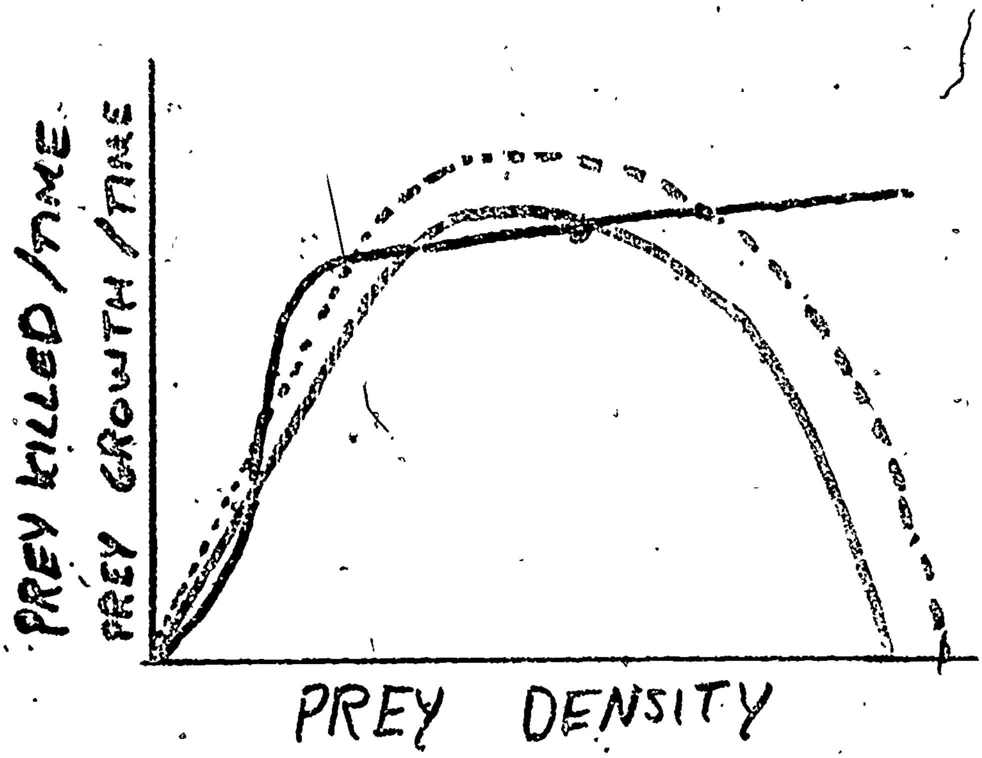
That just looks like this all along. So that doesn't move; no matter what you do to hunter pressure, the predator functional response curve stays the same.

I was going to talk about improper management. Now I'd like to show you an example of game management, and how it can be improperly done, and what the consequences can be to the prey density of an area. Let's say, back to the overheads, that you're managing an area with prey recruitment - predator functional response curves that look like this. (NOTE: the upper half of overhead #6 is displayed.) Let's say your prey density with no hunting pressure at all is at the upper point here. (NOTE: equilibriumm point #3 is pointed to.) So you have really high prey density for the area and everything's going along nicely. It's at a stable equilibrium point and everything. But you want to get some hunters into your area because hunters bring in money, and you always need some money in the area, it seems like. So, to help the financial outlook of your district you think about it and say that you'll allow 3% of the prey to be taken out by hunter harvest. If you do that, the curves would look like this. (NOTE: the bottom half of overhead #6 is uncovered.) The dotted blue line is the original prey recruitment curve with no human hunting taken into account. And the solid blue curve is the curve with the 3% hunter pressure taken into account. That doesn't mean you're killing the hunters! It means the hunters are killing 3% of the prey.

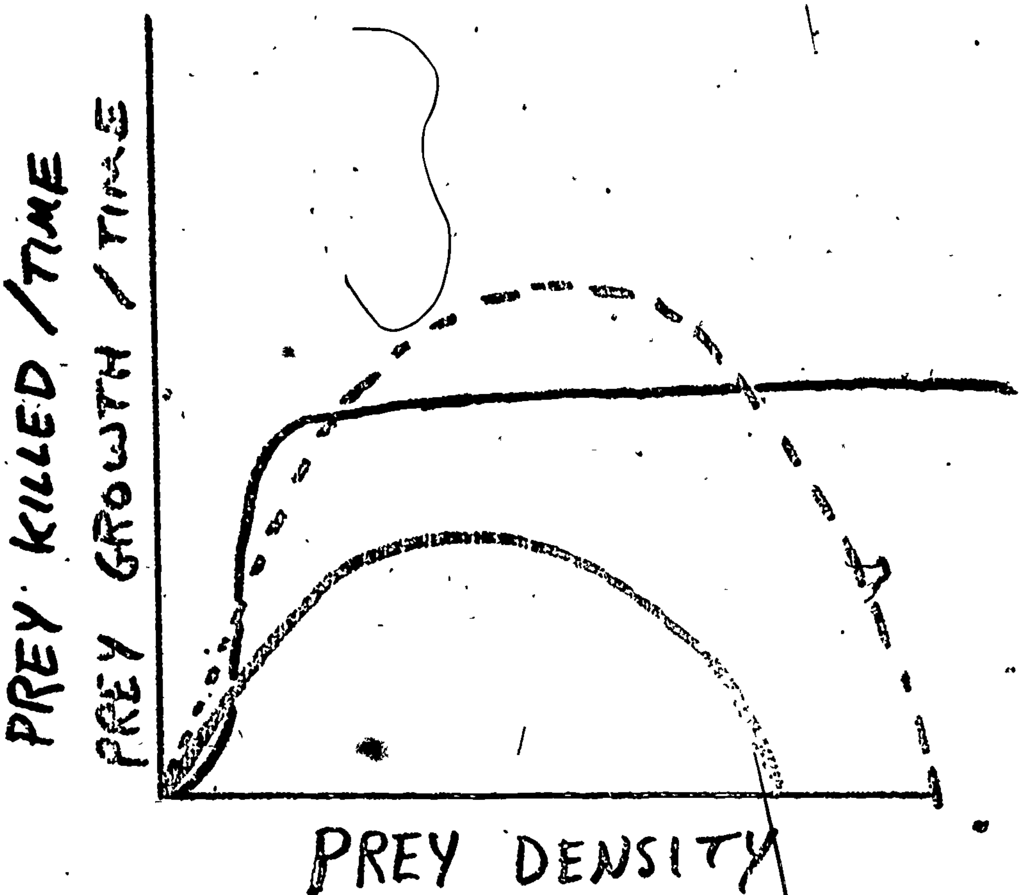
If you look at this you can see that 3% wasn't too bad because your stable equilibrium was there. It's only moved a little bit. So your prey density moves down to here and then stops again. Your prey density hasn't gone down very much.

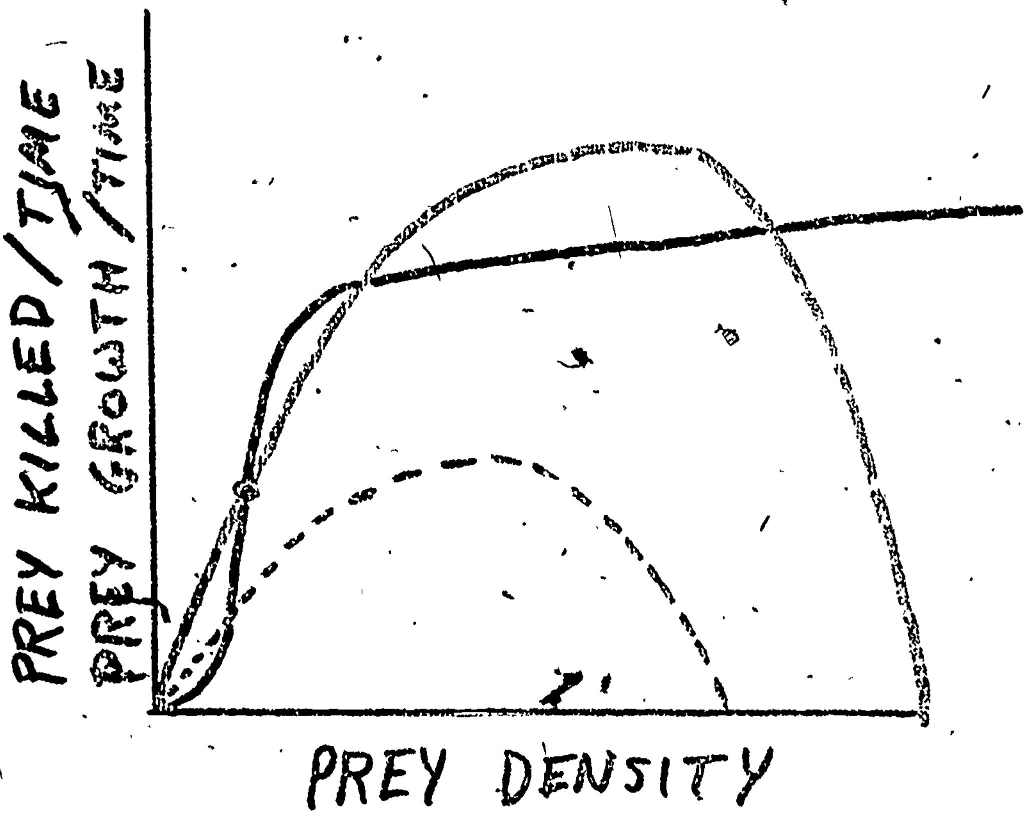
But let's say that you make a mistake and say to take out 15% because things look pretty good. What could happen is this curve. (NOTE: the upper half of overhead #7 is displayed.) If this dotted line is prey recruitment with no hunter pressure figured in, and this solid blue curve is the prey recruitment curve with 15% of the prey population being taken out by hunters. You see that you've lost your


PREY KILLED / TIME
PREY GROWTH / TIME
PREY DENSITY


PREY KILLED / TIME
PREY GROWTH / TIME
PREY DENSITY

OVERHEAD #6


PREY KILLED / TIME
PREY GROWTH / TIME
PREY DENSITY


PREY KILLED / TIME
PREY GROWTH / TIME
PREY DENSITY

OVERHEAD #7

upper stable equilibrium point completely. You've lost your unstable equilibrium point. So if your prey density was up there (NOTE: equilibrium point #3 is pointed to) and suddenly switched to this curve, what would happen to the prey density?

(NOTE: a student gives the correct response.)

It's going to move down because predator functional response, subtractions, are so high from the population compared to additions, that the prey density will move alongthat line until it finally gets down to this equilibrium point. You can see that this equilibrium point is at a low density, extremely low. That could make it possible for a hard winter, or anything, to knock off the prey completely in an area.

If something like this happens, the first thing that most wildlife managers would do would be to take away the hunting pressure and let the prey density move back up to the upper stable equilibrium point. Then you'd have lots of prey again. Then you could have better management.

But if you do that, there's a problem because... (NOTE: the lower half of overhead #7 is uncovered) if this was your old curve, and you took all hunting away, you'd have this new curve. But the problem is that your old equilibrium point was here, and that's where your prey density was, and suddenly you change things around again, your prey density is only going to move up to the first stable equilibrium and it's not going to move beyond there. So you're not going to get your original system back by removing hunting pressure on the prey. That's been a problem. That may be a problem with wildlife management now. They might be able to use these curves someday, once they're developed a little better.

(NOTE: a student raises his hand.)

Yeah, Kyle?

(NOTE: a question is asked concerning habitat improvement to raise the prey recruitment curve.)

That's a possibility. But most wildlife managers don't believe in curves like this or use them or even know about them. This is just one theory on how prey density can move down and suddenly can't move back up for some reason after excessive hunting. The thing is, now, if you have a system with an equilibrium point there (NOTE: the lower equilibrium point is pointed to) it's not going to move up naturally. If you leave it to nature it's just going to stay there because everything is at a stable equilibrium, humming along nicely. But there are other ways of getting the point back up, but you have to intervene and change habitat and things of that sort, like Kyle said.

Any more questions?

I'll throw in a little conclusion because I'm ahead of schedule. What we've talked about, then, is the prey population growth curve and how we got the prey recruitment curve from that. Then we talked about the predator

functional response curve and how that came about; the general shape of it, showing that it's generally increasing until it levels off due to predator satiation.

We talked about how fast the prey density will approach an equilibrium point. We talked about equilibrium points, if they're stable or unstable. We talked about predator carrying capacity and how that changed the functional response curve, moves it up or down. And we also talked about human hunting pressure. Other than that, if there aren't any questions we can relax for seven or eight minutes until the rest of the class comes down. Then we'll take a posttest.

(NOTE: a student raises his hand.)

Got a question, Dale?

(NOTE: a question is asked concerning the theoretical nature of the curves.)

These are quite theoretical right now. The curves themselves are accepted, but when you put them together, there is still alot of theory involved and a lot of argument. Like these started in the 1950's, but since then these curves have not been more developed. People have accepted them from back then and worked with that. But then they don't put predator and prey together, usually. There's got to be a lot of work done before this is accepted.

(NOTE: a question is asked concerning the simplicity of the model.)

There are a lot of environmental parameters that aren't in this model, like hard winters and things of that sort, and different years for vegetative growth. That would move these curves all over the place. There are a lot of studies to be done yet.

Anybody else?

(NOTE: a question is asked concerning why the prey density remains at the lower equilibrium point after hunting pressure is removed.)

The curve itself is the same; it's just that the prey density is stuck down here because when you put on all that hunting pressure the prey density was forced to drop all the way down to this equilibrium point, right? So that means that equilibrium point is right there when you take the hunting pressure off, and these two original curves come about again. So that means that this prey density can only move up to that stable equilibrium point. It can't get up to the upper stable equilibrium. It's kind of caught in the big change there. That's the problem.

(NOTE: the instructor is asked to cover the speed of prey density movement again.)

(NOTE: the axes and curves are drawn on the blackboard.)

You have the two curves. If this is the change in density per time, the predator functional response curve is the negative change. The prey recruitment curve is the positive change. Then if you take the difference between

the two curves, like right here, you have a section that is the net change. So if you have this net change in prey density, then you already know it's going to go in this direction because prey recruitment is the higher curve. Take that length and lay it on its side on the X-axis, and add it to the prey density. If this is the change in the prey density, then you can add that to what the prey density was and get the next time interval's prey density. Like if this time unit is per year, then that would be the change in the prey density per year. So you'd take that much, and for the next year you'd be adding this; taking the whole thing and laying it on its side. You'd come out there, and the next year your prey density would be up this high.

These curves have been developed from Alaska, the caribou, moose herds, and also in Canada.

(NOTE: hallway noise is heard.)

I gather everyone's here, so if there aren't any more questions, we can get this posttest going.

(NOTE: the module group comes in.)

(NOTE: the tests and computer answer sheets are handed out.)

Please don't start the test until I tell you to. Take one copy of the test and one copy of the answer sheet. I'd like it done in pencil if you could get one. The first thing you can do is put your name on the answer sheet and also what you did -- if you were up looking at a module or here.

There are 20 questions; you'll have until on the hour to do this. And please answer on the answer sheet; don't write on the test itself. And notice that the answer sheet goes across with the numbers, not down.

You can start now.

APPENDIX F

Analysis of Covariance

The data to be analyzed consisted of the posttest scores and final course percentages for 24 students. These scores are listed in Table F1.

The Olmstead-Tukey's Corner Test was applied to the data for each group, lecture and module, to check for a relationship between the X (final course percentages) and the Y (posttest scores) variables. A relationship was indicated by the corner test.

Analysis of covariance was applied to the data to compare the lecture and module group posttest scores. This data analysis procedure adjusts the Y variable to the X variable (covariate), then compares the mean of these adjusted Y values. Table F2 summarizes the analysis of covariance results. The calculated F-value was less than one, which indicated no sigificant difference between the means of the adjusted posttest scores for the lecture and module groups.

TABLE F1. The raw scores for the module and lecture groups.

X		Y	
final class percentage		posttest score	
module	lecture	module	lecture
76	87	16	16
75	88	13	20
86	92	20	17
84	91	18	16
68	75	9	11
98	67	17	10
72	75	9	13
78	82	11	17
78	77	18	14
67	80	15	17
79	90	19	11
81	93	17	20

TABLE F2. Analysis of covariance table.
SS(Y'), MS, and F are calculated from the means of the adjusted posttest scores.

Source	df	SS(X)	SS(Y)	SP	SS(Y')	MS	F
Trtmt	1	126.04	0.00	0.00	8.23	8.23	0.98
Error	22(21)	1541.92	285.33	409.83	176.40	8.40	
Total	23(22)	1667.96	285.33	409.83	184.63		

APPENDIX G

Predator Functional Response

Apple Program Listings

Following are the Applesoft program listings for the PFR module. This module consists of four subprograms: PRED FUNCT INTRO, PRED FUNCT1, PRED FUNCT2, and PRED FUNCT3.

```
5 REM PRED FUNCT INTRO
10 REM    PRED FUNCT INTRO IS A SUBPROGRAM OF PREDATOR FUNCTIONAL RESPON
   SE.
20 REM    DESIGNED BY MARK SHALTZ, DR. J. D. SPAIN, AND DR. KENNETH KRAM
   M.
25 REM    PROGRAMMED BY MARK SHALTZ.
26 REM  THIS PROGRAM HAS DEVELOPED BY THE SUMIT I COURSEWARE DEVELOPMENT
    PROJECT, DEPARTMENT OF BIOLOGICAL SCIENCES, MICHIGAN TECHNOLOGICAL UN
    IVERSITY, HOUGHTON, 49931.
27 REM  THIS MATERIAL IS BASED UPON WORK SUPPORTED BY THE NATIONAL SCIENC
    E FOUNDATION UNDER GRANT NUMBER SED-7919051.
28 REM  ANY OPINIONS, FINDINGS, AND CONCLUSIONS OR RECOMMENDATIONS EXPRES
    SED IN THIS PUBLICATION ARE THOSE OF THE AUTHORS AND DO NOT NECESSARI
    LY REFLECT THE VIEWS OF THE NATIONAL SCIENCE FOUNDATION.
50 POKE 232,0: POKE 233,08: SCALE= 1: ROT= 0: HCOLOR= 3
60 D$ = CHR$ (4)
70 PRINT D$;"BLOAD SMALL CHARACTERS,A$800"
100 REM
110 REM    TITLE AND CREDITS ARE DISPLAYED.
120 REM
130  HOME : HGR
140 SCALE= 4: HCOLOR= 3: ROT= 0
150 Z$ = "P  R  E  D  A  T  O  R"
160 XA = 31:YA = 50: GOSUB 6340
170  POKE  - 16368,0
180  SCALE= 2
190 Z$ = "F U N C T I O N A L   R E S P O N S E"
200 XA = 11:YA = 90: GOSUB 6340
210  SCALE= 1
220 PAUSE = 3000: GOSUB 5000
230  HOME : HGR : TEXT :PAUSE = 500: GOSUB 5000
240  VTAB 7
250  PRINT "    THIS MODULE HAS DEVELOPED FOR"
260  VTAB 9
270  PRINT "     THE SUMIT I PROJECT"
280  PRINT "     DEPARTMENT OF BIOLOGICAL SCIENCES"
290  PRINT "     MICHIGAN TECHNOLOGICAL UNIVERSITY"
300  PRINT "     HOUGHTON, MICHIGAN 49931":PAUSE = 6000: GOSUB 5000
310  GOSUB 4050: VTAB 10
320  PRINT "    PREDATORS DEPEND ON AN ACTIVELY     GROWING PREY POPULATIO
     N FOR THEIR         SURVIVAL. IF TOO FEW PREY ARE BORN,    THEN PREDAT
     ORS CANNOT SURVIVE."
330 PAUSE = 1000: GOSUB 5000: VTAB 16
340  PRINT "    TO STUDY THIS RELATIONSHIP OF        PREDATORS TO PREY, WE
     MUST FIRST LOOK ATTHE PREY IN THE ABSENCE OF PREDATORS."
350 PAUSE = 500: GOSUB 5000: GOSUB 5080
360  REM
```

```
370  REM     THE LOGISTIC GROWTH CURVEIS INTRODUCED.
380  REM

390 X$ = "TIME"
400 Y$ = " "
410 YM$ = "50"
420 YM = VAL (YM$)
430 XM = 100
440 X1 = 30
450 Y1 = 109
460 LYA = 70
470 LXA = 80
480  HOME : HGR
490 PAUSE = 500: GOSUB 5000
500  GOSUB 30600
510 Z0 = 1:X0 = 12:Y0 = 94:L$ = "PREY": GOSUB 30780
520 Z0 = 1:X0 = 22:Y0 = 101:L$ = "DENSITY": GOSUB 30780
530 XA = 96:YA = 112
540 Z$ = "100": GOSUB 6340
550 XA = 148:YA = 50
560 Z$ = "HERE IS AN EXAMPLE"
570  GOSUB 6340
580 XA = 141:YA = 60
590 Z$ = "OF A POSSIBLE PREY"
600  GOSUB 6340
610 XA = 141:YA = 70
620 Z$ = "GROWTH CURVE."
630  GOSUB 6340
632 XA = 33:YA = 10
633 Z$ = "PREY POPULATION": GOSUB 6340
634 XA = 40:YA = 20
635 Z$ = "GROWTH CURVE": GOSUB 6340
640  REM

650  REM     THE LOGISTIC GROWTH CURVE IS PLOTTED.
660  REM

670 ZF = 1
680 R = .1
690 K = 50
700 N = .5
710  FOR T = 0 TO 100
720 D1 = R * N * (1 - N / K)
730 N = N + D1
740 X = T:Y = N
750  GOSUB 31000
760  NEXT
770 XA = 0:YA = 129
780 Z$ = "  THE POPULATION GROWS UNTIL IT LEVELS  OFF AT SOME CARRYING CAP
     ACITY."
```

```
790  GOSUB 6340
800  GOSUB 5080: HOME
810 X = 141:Y = 50:XZ = 138:L = 30: GOSUB 5750
820  HOME :X = 0:Y = 129:XZ = 279:L = 20: GOSUB 5750
830  REM
840  REM      A QUESTION IS ASKED CONCERNING THE CURVE ON THE SCREEN.
850  REM
860 XA = 140:YA = 50: IF COUNT = 1 THEN XA = 0
870 Z$ = "  LOOKING AT THIS"
880  GOSUB 6340
890 XA = 140:YA = 60: IF COUNT = 1 THEN XA = 0
900 Z$ = "GRAPH, WHERE DOES": GOSUB 6340
910 XA = 140:YA = 70: IF COUNT = 1 THEN XA = 0
920 Z$ = "THE PREY POPULATION": GOSUB 6340
930 XA = 140:YA = 80: IF COUNT = 1 THEN XA = 0
940 Z$ = "HAVE THE HIGHEST": GOSUB 6340
950 XA = 140:YA = 90: IF COUNT = 1 THEN XA = 0
960 Z$ = "GROWTH RATE?": GOSUB 6340
980 XA = 0:YA = 129
990 Z$ = " A.  AT A LOW PREY DENSITY.": GOSUB 6340
1010 XA = 0:YA = 139
1020 Z$ = " B.  AT A HIGH PREY DENSITY.": GOSUB 6340
1040 XA = 0:YA = 149
1050 Z$ = " C.  SOMEWHERE IN BETWEEN.": GOSUB 6340
1060  VTAB 23
1070  POKE  - 16368,0
1080  INPUT Q$
1090  HOME
1100  IF  LEFT$ (Q$,1) = "A" OR  LEFT$ (Q$,1) = "B" GOTO 1164
1101  IF  LEFT$ (Q$,1) = "C" GOTO 1162
1110 PAUSE = 500: GOSUB 5000: VTAB 22
1120  PRINT "   .PLEASE CHOOSE  A, B, OR  C  ."
1140  GOTO 1070
1162  IF COUNT = 1 THEN  HOME : RETURN
1163  HOME : VTAB 21: PRINT "VERY GOOD!";: GOTO 1168
1164  IF COUNT = 1 THEN  HOME : RETURN
1165  HOME : VTAB 21: PRINT "INCORRECT.";
1168 PAUSE = 500: GOSUB 5000
1170 PAUSE = 500: GOSUB 5000: VTAB 21
1180  PRINT " THE PREY POPULATION HAS      THE HIGHEST GROWTH RATE AT MEDI
    UM        PREY DENSITIES."
1190 PAUSE = 500: GOSUB 5000
1200  GOSUB 5080
1210  REM
```

```
1220  REM     PREY RECRUITMENT IS INTRODUCED.
1230  REM

1240  HOME :X = 140:Y = 50:XZ = 139:L = 50: GOSUB 5750
1250 X = 0:Y = 129:XZ = 279:L = 30: GOSUB 5750
1260 XA = 0:YA = 131
1270 Z$ = "TO BETTER SHOW THIS CHANGE IN GROWTH    RATE AT DIFFERENT DENSI
    TIES, A GRAPH     WITH THE FOLLOWING AXES CAN BE USED."
1280  GOSUB 6340
1290 YM$ = "1.4"
1300 YM =  VAL (YM$)
1310 X1 = 180
1320 X$ = " ":Y$ = " CHANGE": GOSUB 30600
1330 XA = 198:YA = 112
1340 Z$ = "PREY": GOSUB 6340
1350 XA = 190:YA = YA + 8
1360 Z$ = "DENSITY": GOSUB 6340
1370 XA = 256:YA = 112
1380 Z$ = "50": GOSUB 6340
1390  GOSUB 5080: HOME : VTAB 21
1400  HOME :X = 0:Y = 129:XZ = 279:L = 30: GOSUB 5750
1410  GOSUB 4060
1412  PRINT "ARE THE TWO X-AXES THE SAME?"
1413  VTAB 24
1414  POKE  - 16368,0: INPUT Q$: GOSUB 4050
1415  IF  LEFT$ (Q$,1) <  > "Y" AND  LEFT$ (Q$,1) <  > "N" THEN  VTAB 22: PRINT
    "PLEASE ANSWER YES OR NO.": GOTO 1410
1416  IF  LEFT$ (Q$,1) = "N" THEN  PRINT "RIGHT! ";: GOTO 1420
1418  PRINT "WRONG. ";
1420  PRINT "THE X-AXES ARE DIFFERENT."
1422 PAUSE = 500: GOSUB 4000: PRINT "THE POPULATION GROWTH GRAPH HAS TIME
    ON THE X-AXIS, WHILE THE GRAPH ON THE RIGHTHAS PREY DENSITY."
1424 PAUSE = 500: GOSUB 4000
1425  PRINT "ALSO NOTICE THAT                            THE Y-AXES ARE DIFFER
    ENT."
1426 PAUSE = 500: GOSUB 4000
1430  PRINT "DO YOU UNDERSTAND WHAT 'CHANGE' IS ON    THE Y-AXIS OF THE GRA
    PH ON THE RIGHT?"
1432  VTAB 24: POKE  - 16368,0: INPUT Q$: GOSUB 4050
1433  IF  LEFT$ (Q$,1) <  > "Y" AND  LEFT$ (Q$,1) <  > "N" THEN  PRINT "PL
    EASE ANSWER YES OR NO.":PAUSE = 2000: GOSUB 5000: GOSUB 4050: GOTO 14
    30
1434  TEXT
1435  IF  LEFT$ (Q$,1) = "N" GOTO 1450
1436  VTAB 8
1437  PRINT "WHAT DOES 'CHANGE' REPRESENT?":PAUSE = 1000: GOSUB 5000
1438  PRINT
1439  PRINT "A.  CHANGE IN TIME."
1441  PRINT "B.  GAIN IN THE PREY POPULATION."
1443  PRINT "C.  LOSS IN THE PREY DENSITY."
```

```
1445  VTAB 15: POKE  - 16368,0: INPUT Q$
1446  IF  LEFT$ (Q$,1) <  > "A" AND  LEFT$ (Q$,1) <  > "B" AND  LEFT$ (Q$,
    1) <  > "C" THEN  VTAB 14: PRINT "PLEASE ANSWER A, B, OR C.": VTAB 15
    : PRINT "                                                   ": GOTO 1445
1447  GOSUB 4050: VTAB 5: IF  LEFT$ (Q$,1) = "B" THEN  PRINT "THAT'S RIGHT
    . YOU REALLY DID KNOW!": GOTO 1450
1448  PRINT "THAT IS INCORRECT."
1450  VTAB 7: PRINT "'CHANGE' HERE REPRESENTS GAINS          IN THE PREY P
    OPULATION."
1451  PRINT : PRINT "FOR EXAMPLE, IF THE POPULATION GREW      FROM 60 TO 75
     INDIVIDUALS OVER AN          INTERVAL OF TIME, WHAT IS THE CHANGE?"
1452  PRINT : POKE  - 16368,0: INPUT Q$: PRINT : PRINT
1453  IF  LEFT$ (Q$,2) = "15" OR  LEFT$ (Q$,5) = "FIFTE" THEN  PRINT " VER
    Y GOOD!": GOTO 1456
1454  PRINT "THAT'S NOT CORRECT."
1456  PRINT : PRINT "THE CHANGE IS  75 - 60 = 15 ."
1457 PAUSE = 500: GOSUB 4000: POKE  - 16304,0: POKE  - 16297,0
1480  PRINT " NEXT, BOTH GRAPHS WILL BE PLOTTED        AT THE SAME TIME TO S
    HOW THEIR          RELATIONSHIP TO EACH OTHER."
1490 PAUSE = 500: GOSUB 5000
1500 X = 0:Y = 129:XZ = 279:L = 20: GOSUB 5750
1510 XA = 0:YA = 139
1520 Z$ = "  TO PLOT THE CURVES PRESS -RETURN- .": GOSUB 6340
1530  POKE  - 16368,0
1540  VTAB 10: INPUT Q$
1550  HOME :X = 0:Y = 139:XZ = 279:L = 10: GOSUB 5750
1560  REM

1570  REM      PREY RECRUITMENT AND LOGISTIC GROWTH ARE PLOTTED SIMULTANEOU
    SLY.
1580  REM

1590 ZF = 1:ZG = 0
1600 N = .5
1610 X = 31:Y = 39:XZ = 80:L = 69: GOSUB 5750
1620 X = 181:Y = 39:XZ = 80:L = 69: GOSUB 5750
1630  IF COUNT <  > 0 GOTO 1700
1640 XA = 0:YA = 149
1650 Z$ = "TIME": GOSUB 6340
1660 XA = 100:YA = 149
1670 Z$ = "PREY DENSITY": GOSUB 6340
1680 XA = 230:YA = 149
1690 Z$ = "CHANGE": GOSUB 6340
1700  FOR T = 0 TO 100
1710 D1 = R * N * (1 - N / K)
1720 N = N + D1
1730 YM = 50:X1 = 30:XM = 100
1740  IF T > 0 THEN  HPLOT X9,Y9
1750 X = T:Y = N: GOSUB 31000
1760 X9 = X0:Y9 = Y0
1770  IF T = 0 THEN ZG = 0
```

```
1780 YM = 1.4:X1 = 180:XM = 50
1790  IF T > 0 THEN  HPLOT X8,Y8
1800 X = N:Y = D1: GOSUB 31000
1810 X8 = X0:Y8 = Y0
1820  IF COUNT < > 0 GOTO 1920
1830  IF T = 0 OR  INT (T / 25) <  > T / 25 GOTO 1920
1840  HOME
1850  VTAB 21: PRINT T, INT (N * 100) / 100, INT (D1 * 100) / 100
1860 PAUSE = 500: GOSUB 5000
1870  IF T = 25 THEN  PRINT "NOTICE THAT AT LOW PREY DENSITY THE     CHANG
     E IN PREY DENSITY IS LOW."
1880  IF T = 50 THEN  PRINT "  THE HIGHEST CHANGE OCCURS AT          MEDIU
     M PREY DENSITY."
1890  IF T = 75 THEN  PRINT "  AT HIGHER PREY DENSITIES THE CHANGE   DECRE
     ASES."
1900 PAUSE = 500: GOSUB 5000: GOSUB 5080
1910  HOME
1920  NEXT
1930 PAUSE = 500: GOSUB 5000
1940  HOME :X = 0:Y = 149:XZ = 279:L = 10: GOSUB 5750
1950  GOSUB 4060
1960  PRINT "  THE GRAPH ON THE RIGHT REPRESENTS ALL PREY BIRTHS MINUS NON
     -PREDATOR DEATHS.  IT IS CALLED A  PREY RECRUITMENT CURVE."
1962 XA = 168:YA = 10
1964 Z$ = "PREY RECRUITMENT": GOSUB 6340
1965 XA = 196:YA = 20
1966 Z$ = "CURVE": GOSUB 6340
1970 PAUSE = 500: GOSUB 4000
1990  PRINT "   WOULD YOU LIKE TO SEE THE CURVES    PLOTTED AGAIN?"
2000  VTAB 24
2010  INPUT Q$
2020  HOME :PAUSE = 500: GOSUB 5000
2030  IF  LEFT$ (Q$,1) = "Y" THEN COUNT = 1: GOTO 1590
2040 X = 0:Y = 0:XZ = 140:L = 119: GOSUB 5750
2050  REM

2060  REM       THE SAME QUESTION ASKED EARLIER IS NOW ASKED USING A NEW GR
     APH.
2070  REM

2080 COUNT = 1: GOSUB 860
2090  VTAB 21
2100  IF  LEFT$ (Q$,1) = "C" THEN  PRINT "  CORRECT. THE HIGHEST POPULATIO
     N GROWTHOCCURS AT THE PEAK IN THE CURVE, SO -C- IS CORRECT."
2110  IF  LEFT$ (Q$,1) = "C" GOTO 2130
2120  PRINT "  THAT IS INCORRECT. THE HIGHEST POPULA-TION GROWTH OCCURS AT
     THE PEAK IN THE   CURVE, SO  -C-  IS THE CORRECT ANSWER."
2130 PAUSE = 2000: GOSUB 5000: GOSUB 5080: HOME
2140 X = 0:Y = 50:XZ = 139:L = 50: GOSUB 5750
2150 X = 0:Y = 129:XZ = 279:L = 30: GOSUB 5750
2160 XA = 0:YA = 50
```

```
2170 Z$ = "  IN THIS MODULE WE"
2180  GOSUB 6340
2190 XA = 0:YA = 60
2200 Z$ = "WILL BE WORKING WITH"
2210  GOSUB 6340
2220 XA = 0:YA = 70
2230 Z$ = "RECRUITMENT CURVES."
2240  GOSUB 6340
2250 PAUSE = 500: GOSUB 5000: GOSUB 5080
2260  REM
2270  REM     THE RELATIONSHIP OF THE PREDATOR IS INTRODUCED.
2280  REM
2290  HOME : HGR : TEXT
2300  VTAB 7
2310  PRINT "    WE'VE LOOKED AT THE PREY IN THE     ABSENCE OF PREDATORS
AND DEVELOPED THE  PREY RECRUITMENT CURVE."
2320  VTAB 12
2330  PRINT "   NEXT LET'S LOOK AT THE PREDATORS."
2340 PAUSE = 500: GOSUB 4000: VTAB 12
2350  PRINT "    A SINGLE PREDATOR WILL KILL AND EAT A CERTAIN NUMBER OF T
HE PREY AVAILABLE  IN A GIVEN AMOUNT OF TIME."
2360 PAUSE = 500: GOSUB 4000: HGR
2370  PRINT " WE WILL PLOT PREY KILLED PER PREDATOR  (PER UNIT OF TIME) AS
 A FUNCTION           OF PREY DENSITY."
2375 CHART = 1
2380 X$ = "PREY DENSITY":Y$ = "PREY KILLED/TIME"
2390 YM$ = "50":YM =  VAL (YM$)
2400 XM = 50
2410 X1 = 50
2420 Y1 = 129
2430 LYA = 115
2440 LXA = 125
2450  GOSUB 30600
2452 PAUSE = 500: GOSUB 4000
2454  PRINT " AT LOW PREY DENSITIES A PREDATOR WILL  TEND TO KILL AND CONS
UME NEARLY EVERY   PREY IT ENCOUNTERS."
2455 PAUSE = 500: GOSUB 4000
2456  PRINT " THE CURVE AT LOW PREY DENSITIES, THEN, WILL BE CONSTANTLY IN
CREASING. AS MORE  PREY BECOME AVAILABLE, MORE ARE KILLED."
2460 ZF = 1
2465  HPLOT 50,129
2466 A = 50:B = 7
2470  FOR T = 0 TO 50
2480 Y = A * T / (T + B)
2500 X = T
2505  IF T = 7 GOTO 2530
2507  IF T = 23 GOTO 2595
2510  GOSUB 31000
2520  NEXT
```

```
2525  GOTO 2620
2530 PAUSE = 500: GOSUB 4000
2560  PRINT "AS PREY DENSITY INCREASES, THE PREDATOR SPENDS LESS TIME SEAR
     CHING FOR PREY       AND MORE TIME EATING ITS KILL."
2570 PAUSE = 500: GOSUB 4000
2580  PRINT " THE AFFECT IS THAT THE CURVE BEGINS TO LEVEL OFF AS THE PRED
     ATOR SPENDS LESS   TIME SEARCHING FOR PREY."
2590 PAUSE = 500: GOSUB 5000: GOTO 2510
2595 PAUSE = 500: GOSUB 4000
2600  PRINT " THE CURVE LEVELS OFF AT VERY HIGH PREY DENSITIES DUE TO TWO
     FACTORS:          SATIATION AND PROCESSING TIME."
2610  GOTO 2510
2620 PAUSE = 500: GOSUB 4000: TEXT
2630  VTAB 10
2640  PRINT "SATIATION REFERS TO THE FACT THAT        A PREDATOR CAN EAT ON
     LY SO MANY PREY,    EVEN IF MORE AVAILABLE."
2650  PRINT "(THE PREDATOR GETS FULL.)"
2660 PAUSE = 500: GOSUB 5000: VTAB 23: INPUT "          PRESS -RETURN- TO
     CONTINUE";Q$: VTAB 23: PRINT "
                                                                          "
2665  GOSUB 4060: VTAB 17
2670  PRINT " BUT THE CURVE ALSO LEVELS OFF BECAUSE  THE PREDATOR SPENDS L
     ITTLE TIME           SEARCHING. IT IS MAINLY USING ITS TIME  CONSUMING
     EACH KILL IT MAKES."
2680 PAUSE = 500: GOSUB 4000: POKE  - 16304,0: POKE  - 16297,0
2690  PRINT "THIS IS CALLED A                         PREDATOR FUNCTIONAL
     RESPONSE CURVE."
2700 XA = 65:YA = 0
2710 Z$ = "PREDATOR FUNCTIONAL": GOSUB 6340
2720 XA = 82:YA = 10
2730 Z$ = "RESPONSE CURVE": GOSUB 6340
2740 PAUSE = 500: GOSUB 4000
2750  PRINT " IT REPRESENTS THE NUMBER OF PREY        A SINGLE PREDATOR WIL
     L KILL AS             A FUNCTION OF PREY DENSITY."
2760 PAUSE = 500: GOSUB 4000: HGR : TEXT : VTAB 7
2770  PRINT "  THE PREDATOR FUNCTIONAL RESPONSE CURVEIN THE PREVIOUS EXAMP
     LE WAS FOR            A SINGLE PREDATOR."
2780 PAUSE = 500: GOSUB 5000: VTAB 23: INPUT "          PRESS -RETURN- TO CONT
     INUE";Q$
2785  VTAB 23: PRINT "                                          "
2786  VTAB 11
2787  PRINT " BUT IN NATURE WE'RE USUALLY INTERESTED IN A POPULATION OF PR
     EDATORS IN AN AREA,NOT JUST A SINGLE PREDATOR."
2790  VTAB 15
2800  PRINT "PREDATOR FUNCTIONAL RESPONSE CAN         ALSO BE LOOKED AT FOR
     A POPULATION        OF PREDATORS."
2810 PAUSE = 500: GOSUB 4000
2820  VTAB 10
2830  PRINT "  LET'S LOOK AT THE FUNCTIONAL RESPONSE FOR A POPULATION OF P
     REDATORS AND THEN  EXPLORE THE RELATIONSHIP TO THE PREY   RECRUITMEN
     T CURVE."
```

```
2840  VTAB 21: PRINT " (PLEASE BE PATIENT. PROGRAM LOADING.)"
3800  REM
3810  REM    THE SUBPROGRAM PRED FUNCT1 IS RUN.
3820  REM
3830 D$ =  CHR$ (4)
3840  PRINT D$;"RUN PRED FUNCT1"
3850  END
4000  REM
4010  REM   PAUSE, RETURN, PAUSE, VTAB SUBROUTINE.
4020  REM
4030  GOSUB 5000
4040  GOSUB 5080
4050  HOME
4060 PAUSE = 500: GOSUB 5000
4070  VTAB 21
4080  RETURN
4081  REM
4995  REM
4996  REM ******************
4997  REM *** SUBROUTINES ***
4998  REM ******************
5000  REM
5010  REM      PAUSE SUBROUTINE.
5020  REM      VARIABLES TO BE PROVIDED:
5030  REM      D  = LENGTH OF PAUSE.
5040  REM
5050  FOR PS = 1 TO PAUSE
5060  NEXT
5065  RETURN
5070  REM
5080  REM
5090  REM      PRESS -RETURN- SUBROUTINE.
5100  REM
5105  POKE  - 16368,0
5110  VTAB 24
5120  INPUT "                PRESS -RETURN- TO CONTINUE";Q$
5130  RETURN
5750  REM
```

```
5760  REM     SUBROUTINE THAT BLACKS OUT A RECTANGLE ON THE HGR SCREEN.
5770  REM -VARIABLES THAT MUST BE PROVIDED-
5780  REM     X = STARTING X COORDINATE
5790  REM     Y = STARTING Y COORDINATE
5800  REM     XZ = LENGTH OF RECTANGLE ALONG THE X AXIS.
5810  REM     L = WIDTH OF RECTANGLE ALONG THE Y AXIS.
5820  REM
5830  HCOLOR= 0
5840  FOR TA = 0 TO L
5850  HPLOT X,TA + Y TO X + XZ,TA + Y
5860  NEXT TA
5870  HCOLOR= 3
5880  RETURN
6240  REM
6250  REM     SUBROUTINE THAT DRAWS A STRING ON THE HGR SCREEN.
6260  REM -VARIABLES THAT MUST BE PROVIDED-
6270  REM   XA = INITIAL X POSITION
6280  REM   YA = INITIAL Y POSITION
6290  REM   Z$ = STRING, IN QOUTATION MARKS
6300  REM
6310 YA = 0: HOME : HGR
6320 XA = 0:YA = YA + 10
6340  FOR Z = 1 TO  LEN (Z$)
6345  IF Z = 1 THEN 6360
6350 XA = XA + 7
6360 ZZ =  ASC ( MID$ (Z$,Z,1))
6370  IF ZZ > 32 THEN 6420
6380  IF ZZ < 2 THEN 6410
6390  IF XA < 279 THEN 6470
6400 XA = 0:YA = YA + 10: GOTO 6470
6410 FLAG = FLAG + 1:XA = XA - 7: GOTO 6470
6420  IF  INT (FLAG / 2) = FLAG / 2 THEN 6440
6430 ZZ = ZZ - 64
6440  IF XA < 279 THEN 6460
6450 XA = 0:YA = YA + 10
6460  DRAW ZZ AT XA,YA
6470  NEXT Z
6480  RETURN
6481  REM

30600  REM   AXES AND UNITS FOR GR           APHS***********************
   ***********************************************
30610  REM  SUBROUTINE DEVELOPED BY J. SPAIN ... MICHIGAN TECH UNIV.
30620  REM  DEFINE X$=UNITS ON THE X AXIS
30630  REM  DEFINE Y$=VARIABLE PLOTTED ON Y AXIS
30640  REM  DEFINE YM$=MAXIMUM UNITS ON THE Y AXIS
30641  REM
```

```
30650  HCOLOR= 3
30660  HPLOT X1,Y1 - LYA TO X1,Y1 TO X1 + LXA + 9,Y1
30670  REM  LABEL X AXIS AS REQ. 36 CHAR.MAX
30680  REM  X$ = "0      XAXIS     100" ETC.
30690 Z0 = 0:L$ = X$:X0 = X1 + 7:Y0 = Y1 + 8
30700  GOSUB 30780
30710  REM  LABEL Y AXIS AS REQUIRED
30720 Z0 = 1:L$ = Y$:X0 = X1 - 8:Y0 = Y1 - 2
30730  GOSUB 30780
30735  IF CHART = 1 GOTO 30755
30740  REM  UNITS ON THE Y AXIS..YM$=Y MAX.
30750 Z0 = 0:X0 = X1 - LEN (YM$) * 7:Y0 = (Y1 - LYA) + 10:L$ = YM$
30755  GOSUB 30850
30756  IF CHART = 1 GOTO 30770
30760  DRAW 48 AT X1 - 10,Y1 - 4
30770  RETURN
30780  REM  ALPHANUMERIC CHARACTERS FOR HGR
30790  REM  THE FOLLOWING MUST BE DEFINED
30800  REM  BEFORE ENTERING THE SUBROUTINE
30810  REM  L$ = "CHARACTER STRING"
30820  REM  Y0 = THE INITIAL Y POSITION
30830  REM  X0 = THE INITIAL X POSITION
30840  REM  SET Z0 = 0 IF PRINTING HORIZONTAL
30850  REM  SET Z0 = 1 IF PRINTING VERTICALLY
30860  FOR Z = 1 TO  LEN (L$):Z3 =  ASC ( MID$ (L$,Z,1))
30870  IF Z0 < > 0 THEN  GOTO 30900
30880  IF Z3 > 64 THEN  DRAW Z3 - 64 AT X0 + (Z - 1) * 7,Y0 - 5: GOTO 3093
    0
30890  DRAW Z3 AT X0 + (Z - 1) * 7,Y0 - 5: GOTO 30930
30900  ROT= 48: IF Z3 > 64 THEN  DRAW Z3 - 64 AT X0 - 5,Y0 - (Z - 1) * 7: GOTO
    30930
30910  IF Z3 < 33 THEN  GOTO 30930
30920  DRAW Z3 AT X0 - 5,Y0 - (Z - 1) * 7
30930  ROT= 0: NEXT Z
30940  RETURN
31000  REM

31010  REM   SCALE AND PLOT POINT FOR DEFINED X AND Y
31020  REM  FOR LINE PLOT MAKE ZF=1
31030  REM

31040 X0 = X1 + X * LXA / XM
31050 Y0 = Y1 - Y * LYA / YM
31060  IF X0 > 279 OR X0 < 0 OR Y0 > 149 OR Y0 < 0 GOTO 31080
31070  IF Z6 = 1 THEN  HPLOT  TO X0,Y0: GOTO 31080
31075  HPLOT X0,Y0: IF ZF = 1 THEN Z6 = 1
31080  RETURN
```

```
5  REM  PRED FUNCT1
10  REM   PRED FUNCT1 IS A SUBPROGRAM OF PREDATOR FUNCTIONAL RESPONSE.
12  REM   PROGRAMMED BY MARK SHALTZ
15  REM  THIS PROGRAM WAS DEVELOPED BY THE SUMIT I COURSEWARE DEVELOPMENT
     PROJECT, DEPARTMENT OF BIOLOGICAL SCIENCES, MICHIGAN TECHNOLOGICAL UN
     IVERSITY, HOUGHTON, MI 49931.
20  REM  THIS MATERIAL IS BASED UPON WORK SUPPORTED BY THE NATIONAL SCIENC
     E FOUNDATION UNDER GRANT NUMBER SED-7919051.
25  REM  ANY OPINIONS, FINDINGS, AND CONCLUSIONS OR RECOMMENDATIONS EXPRES
     SED IN THIS PUBLICATION ARE THOSE OF THE AUTHORS AND DO NOT NECESSARI
     LY REFLECT THE VIEWS OF THE NATIONAL SCIENCE FOUNDATION.
100  DIM Y1(101),X2(101),Y2(101)
110 X$ = "DENSITY OF PREY POPULATION"
120 Y$ = "PREY GROWTH / TIME"
125  VTAB 21: PRINT "
130 PAUSE = 500: GOSUB 4500
132  HGR
134  PRINT "  FIRST WE'LL GRAPH THE PREY RECRUITMENT CURVE FOR THE PREY OF
      AN AREA."
150  REM

160  REM     THE GRAPH IS DRAWN AND LABELLED.
170  REM

180  GOSUB 5280
190 WRITE = 0
260 ZF = 1
290  REM

300  REM  THE PREY RECRUITMENT CURVE IS DRAWN.
310  REM

320  HCOLOR= 3
330  HPLOT 23,149
340  FOR I = 0 TO 100
350  READ X2(I),Y1(I),Y2(I)
360  HPLOT  TO X2(I),Y1(I)
370  NEXT
380 PAUSE = 1: GOSUB 4500
420  PRINT " THIS CURVE REPRESENTS THE CHANGE IN   PREY DENSITY RESULTING
      FROM ALL PREY    BIRTHS MINUS ALL NON-PREDATOR DEATHS."
430 PAUSE = 500: GOSUB 4500
460  REM

470  REM     PREDATOR FUNCTIONAL RESPONSE IS INTRODUCED.
480  REM

490  VTAB 22
510  PRINT "    NEXT, THE NUMBER OF PREY EATEN BY A FIXED NUMBER OF PREDAT
     ORS IS GRAPHED."
```

```
520 PAUSE = 1000: GOSUB 4500: VTAB 22
530 PRINT "    FOR THIS GRAPH THE Y-AXIS IS THE    NUMBER OF PREY EATEN B
    Y THE PREDATORS."
540 PAUSE = 4000: GOSUB 5000
550 HCOLOR= 5
560 L$ = "PREY EATEN / TIME":X0 = 0:Y0 = 140: GOSUB 5450
570 X0 = 1: GOSUB 5450
580 HCOLOR= 3
590 GOSUB 4540
620 YM = 150
630 IF COUNT = 1 THEN HCOLOR= 0: DRAW 49 AT 30,124: DRAW 50 AT 104,48: DRAW
    51 AT 195,24
640 HCOLOR= 5
650 HPLOT 23,149
660 K = 110
670 E = 2.5
680 DD = 300
690 YS = 8:YU = 30:YE = 69
700 VTAB 22
710 REM
720 REM    THE PREDATOR FUNCTIONAL RESPONSE CURVE IS PLOTTED.
730 REM
740 HCOLOR= 5
750 PAUSE = 500
760 FOR N = 0 TO 100
770 IF COUNT > 0 THEN GOTO 880
780 IF N = 5 OR N = 12 THEN HOME : VTAB 21: GOSUB 5000
790 IF N = 45 THEN HOME : VTAB 22: GOSUB 5000
800 IF N = 5 THEN PRINT " AT VERY LOW PREY DENSITY THE PREDATORSTURN TO
     OTHER SOURCES OF FOOD AND THERE-FOR CAPTURE FEW PREY."
810 IF N = 12 THEN PRINT " AS THE PREY DENSITY INCREASES, PRED- ATORS
    RECOGNIZE AND CAPTURE PREY MORE   EFFICIENTLY, SO THE CURVE INCREASES
         SHARPLY.";
820 IF N = 12 THEN PAUSE = 3000: GOSUB 5000:PAUSE = 1000: INPUT " PRESS -
    RETURN- TO CONT";Q$
830 IF N = 12 THEN HOME
840 IF N = 45 THEN PRINT " PREDATOR CAPTURE RATE LEVELS OFF AT   HIGH P
    REY LEVELS DUE TO SATIATION.": GOSUB 5080: HOME
860 IF N = 65 THEN VTAB 21: PRINT" ALTHOUGH PREY DENSITY IS NOW VERY HI
    GH,THE PREDATOR FUNCTIONAL RESPONSE        INCREASES LITTLE."
870 IF N = 5 THEN GOSUB 5000: GOSUB 5080: HOME
880 HPLOT TO X2(N),Y2(N)
890 NEXT
900 GOSUB 4540
910 IF COUNT > 0 GOTO 2410
920 GOSUB 4550
930 PRINT "RECALL THAT THIS FUNCTIONAL RESPONSE    CURVE IS FOR A FIXED N
    UMBER OF           PREDATORS."
940 PAUSE = 500: GOSUB 4500
```

```
975  REM
976  REM     THE IDEA OF POSITIVE AND NEGATIVE GRAPHS IS DISCUSSED.
977  REM
980  TEXT : HOME :PAUSE = 500: GOSUB 5000
990  VTAB 7
1000  PRINT "    BOTH OF THE CURVES JUST GRAPHED      EXPRESS CHANGE IN THE
      PREY DENSITY."
1010 PAUSE = 1000: GOSUB 5000: VTAB 10
1020  PRINT "    THE PREY RECRUITMENT CURVE IS       POSITIVE BECAUSE IT R
     EPRESENTS ADDITIONSTO THE PREY POPULATION."
1030 PAUSE = 1000: GOSUB 5000: VTAB 14
1040  PRINT "    THE PREDATOR FUNCTIONAL RESPONSE     CURVE IS NEGATIVE BEC
     AUSE IT REPRESENTS SUBTRACTIONS FROM THE PREY POPULATION."
1050 PAUSE = 500: GOSUB 4500: POKE  - 16304,0: POKE  - 16297,0
1090  PRINT "IN THIS PROGRAM, POSITIVE CHANGES WILL  BE GRAPHED AS A WHITE
      LINE, AND NEGATIVECHANGES WILL BE COLORED (OR DOTTED)."
1100 PAUSE = 1000: GOSUB 4500: VTAB 22: POKE  - 16368,0
1110  HOME : VTAB 21
1140  REM
1150  REM    A QUESTION REGARDING THE NUMBER OF EQUILIBRIUM POINTS IS ASK
     ED.
1160  REM
1165  INPUT "    THIS IS AN EXAMPLE OF A              MULTI-EQUILIBRIA SYST
     EM. HOW MANY        EQUILIBRIUM POINTS ARE THERE?";Q$
1170  IF  LEFT$ (Q$,1) = "4" OR  LEFT$ (Q$,2) = "FO" GOTO 1172
1171  GOTO 1180
1172  GOSUB 4550
1173  PRINT "YOU ANSWERED 4, BUT 3 IS THE CORRECT    ANSWER."
1174 PAUSE = 1000: GOSUB 4500
1175  PRINT "POSSIBLY YOU COUNTED (0,0) AS AN        EQUILIBRIUM POINT. (0
     ,0) IS NOT USUALLY INCLUDED."
1176  GOTO 1210
1180  IF  LEFT$ (Q$,1) = "3" OR  LEFT$ (Q$,3) = "THR" GOTO 1230
1190  GOSUB 4550: VTAB 22
1200  PRINT "  EQUILIBRIUM POINTS OCCUR WHERE THE    TWO CURVES INTERSECT.
     "
1210 PAUSE = 1000: GOSUB 5000: GOSUB 5080
1220  GOTO 1110
1230  GOSUB 4550
1260  PRINT "  THAT'S CORRECT. THERE ARE THREE       EQUILIBRIUM POINTS, O
     NE AT EACH          INTERSECTION."
1270 PAUSE = 1000: GOSUB 5000
1280  HCOLOR= 3
1290  DRAW 49 AT 30,113
1300  DRAW 50 AT 88,43
1310  DRAW 51 AT 198,36
1320 PAUSE = 500: GOSUB 4500: VTAB 22
1360  PRINT "    AN EQUILIBRIUM POINT CAN BE STABLE  OR UNSTABLE."
```

```
1370  GOSUB 4540: VTAB 22
1410  PRINT "    AS AN EXAMPLE, LET'S LOOK AT         EQUILIBRIUM POINT # 1
."
1420 PAUSE = 1000: GOSUB 5000
1430  FOR I = 1 TO 6
1440  HCOLOR= 0
1450  DRAW 49 AT 30,113
1460 PAUSE = 500: GOSUB 5000
1470  HCOLOR= 3
1480  DRAW 49 AT 30,113
1490  GOSUB 5000
1500  NEXT
1510  REM
1520  REM   EQUILIBRIUM POINT #1 IS USED IN A SIMULATION REGARDING STABI
LITY.
1530  REM
1540 PAUSE = 500: GOSUB 4500: VTAB 22
1570  PRINT "IF THE PREY DENSITY IS BELOW POINT #1,  ADDITIONS TO THE PREY
 DENSITY (WHITE      CURVE) ARE GREATER THAN SUBTRACTIONS     FROM IT (C
OLORED CURVE).";
1580  FOR I = 1 TO YS
1590  HCOLOR= 3
1600  HPLOT X2(I),Y1(I) TO X2(I),Y2(I)
1610  NEXT
1620  HCOLOR= 5: HPLOT 23,149
1630  FOR I = 0 TO YS
1640  HPLOT  TO X2(I),Y2(I)
1650  NEXT
1660  HCOLOR= 3
1670 PAUSE = 2000: GOSUB 5000
1680  POKE  - 16368,0
1690  INPUT " PRESS -RETURN-";Q$
1700  GOSUB 4550
1730  PRINT "  THE NET RESULT IS THAT THE PREY        DENSITY INCREASES UNT
IL IT REACHES       EQUILIBRIUM POINT #1 ."
1740 PAUSE = 500: GOSUB 5000
1750 A = 0:B = YS:ST = 1
1760  GOSUB 4000
1770  HCOLOR= 5
1780  HPLOT 25,149
1790  FOR I = 0 TO YS
1800  HPLOT  TO X2(I),Y2(I)
1810  NEXT
1820  HCOLOR= 3
1830 PAUSE = 1: GOSUB 4500
1870  PRINT "  IF THE PREY DENSITY IS JUST ABOVE      POINT #1, SUBTRACTION
S (COLORED CURVE)  ARE GREATER THAN ADDITIONS              (WHITE CUR
VE).";
1880  FOR I = YU TO YS STEP  - 1
```

```
1890  HCOLOR= 3
1900  HPLOT X2(I),Y1(I) TO X2(I),Y2(I)
1910  NEXT
1920  HCOLOR= 5: HPLOT X2(YU),Y2(YU)
1930  FOR I = YU TO YS STEP  - 1
1940  HPLOT  TO X2(I),Y2(I)
1950  NEXT
1960  HCOLOR= 3
1970 PAUSE = 1000: GOSUB 5000
1980  POKE  - 16368,0
1990  INPUT "        PRESS RETURN";Q$
2000  GOSUB 4550
2030  PRINT "  A PREY DENSITY IN THIS AREA, THEN,   WILL TEND TO DECREASE
      UNTIL IT REACHES  EQUILIBRIUM POINT #1 ."
2040 A = YU:B = YS:ST =  -1
2050  GOSUB 4000
2060  HCOLOR= 5
2070  HPLOT X2(YU),Y2(YU)
2080  FOR I = YU TO YS STEP  - 1
2090  HPLOT  TO X2(I),Y2(I)
2100  NEXT
2110  HCOLOR= 3
2120 PAUSE = 1: GOSUB 4500
2160  PRINT "  THE NET EFFECT IS THAT ANY PREY DEN-  SITY IN THESE REGIONS
      WILL TEND TO MOVE TO THE EQUILIBRIUM POINT #1."
2170 LG = 150
2180 CE = 1
2190  GOSUB 4100
2200  HCOLOR= 5: HPLOT 25,149
2210  FOR I = 0 TO YU
2220  HPLOT  TO X2(I),Y2(I)
2230  NEXT
2240 PAUSE = 1: GOSUB 4500
2260  PRINT "  BECAUSE ANY PREY DENSITY IN THE AREA  OF POINT #1 WILL MOVE
      TO THAT POINT, IT IS CALLED A STABLE EQUILIBRIUM POINT."
2270 PAUSE = 1000: GOSUB 4500
2285  REM

2286  REM      A QUESTION REGARDING OTHER STABLE EQUILIBRIUM POINTS IS ASKE
     D.
2287  REM

2310  PRINT "     EQUILIBRIUM POINT #1 IS STABLE.":PAUSE = 1000: GOSUB 5000

2320  POKE  - 16368,0
2330  VTAB 23
2340  INPUT "  WHICH OTHER EQUILIBRIUM POINT          IS STABLE?";Q$
2350  GOSUB 4550
2355  IF  LEFT$ (Q$,1) = "3" OR  LEFT$ (Q$,3) = "THR" THEN  PRINT "VERY GO
     OD!": GOTO 2360
```

```
2356 PRINT "NO."
2360 PRINT "EQUILIBRIUM POINT #3 IS ALSO STABLE.":PAUSE = 500: GOSUB 4500
2370 VTAB 21: PRINT "  WATCH THE GRAPH TO GET THE OVERALL   IDEA OF WHER
    E PREY DENSITY WILL GO."
2380 PAUSE = 1000: GOSUB 5000
2390 VTAB 23
2400 PRINT " PRESS -RETURN- WHEN THROUGH";Q$
2410 CE = 0:LG = 100000: GOSUB 4100
2420 GOSUB 4550: VTAB 22
2450 IF PEEK ( - 16384) = 141 THEN POKE - 16368,0
2460 REM
2470 REM   PREDATOR CARRYING CAPACITY IS USED AS A PARAMETER TO BE VARI
    ED.
2480 REM
2490 HOME : HGR : TEXT : VTAB 1
2505 PRINT "   THE SHAPE OF THE PREDATOR FUNCTIONALRESPONSE CURVE IS INF
    LUENCED BY THE    PREDATOR CARRYING CAPACITY."
2507 GOSUB 5280
2510 HCOLOR= 5
2520 L$ = "PREY EATEN / YR":X0 = 0:Y0 = 140: GOSUB 5450
2530 X0 = 1: GOSUB 5450
2540 HCOLOR= 3
2550 VTAB 3
2560 HPLOT 25,149
2570 XM = 100:YM = .3
2590 REM
2600 REM  THE PREY RECRUITMENT CURVE IS DRAWN.
2610 REM
2620 R = .01
2630 K = 100
2640 FOR N = 0 TO 100
2650 IF N = 60 THEN VTAB 7: PRINT "    WILL THE PREDATOR FUNCTIONAL
     RESPONSE CURVE GO UP OR DOWN WHEN THE   PREDATOR CARRYING CAPACITY
    IS RAISED?"
2660 IF N = 90 THEN PRINT : POKE - 16368,0: INPUT Q$
2670 HPLOT TO X2(N),Y1(N)
2680 NEXT
2681 VTAB 13
2682 IF LEFT$ (Q$,1) = "U" THEN PRINT "THAT'S RIGHT!": GOTO 2700
2685 PRINT "THAT'S NOT RIGHT."
2700 K = 110
2710 YM = 150
2720 HCOLOR= 5
2730 HPLOT 25,149
2740 FOR N = 0 TO 100
2750 IF COUNT > 0 THEN HCOLOR= 5: GOTO 2800
```

```
2760  IF N = 5 THEN  PRINT : PRINT "  IT WILL GO UP BECAUSE A HIGHER CARRY
   - ING CAPACITY WILL ALLOW MORE PREDATORS  TO SURVIVE IN THE SYSTEM."
2770  IF N = 50 THEN  PRINT : PRINT "  MORE PREDATORS WILL EAT MORE PREY."
2780  HPLOT  TO X2(N),Y2(N)
2790  GOTO 2860
2800 Y = K * N ^ E / (N ^ E + DD)
2810 X = N
2820  GOSUB 5610
2830  REM
2840  REM    THE PREDATOR CARRYING CAPACITY IS CHANGED BY THE USER.
2850  REM
2860  NEXT : IF COUNT <  > 0 GOTO 2930
2870 PAUSE = 1: GOSUB 4500
2880  VTAB 10
2890  PRINT "    TRY A HIGHER PREDATOR CARRYING        CAPACITY TO SEE THIS
   DEMONSTRATED."
2900 PAUSE = 1000: GOSUB 5000
2910  VTAB 20
2920  PRINT "  PRESENT CARRYING CAPACITY = ";K
2930  IF COUNT <  > 0 THEN  HOME : VTAB 22: INPUT " WOULD YOU LIKE TO CHAN
   GE THE CARRYING  CAPACITY AGAIN? ";Q$
2940  IF  LEFT$ (Q$,1) = "Y" THEN  HOME : VTAB 22: PRINT "  FORMER CARRYIN
   G CAPACITY = "K
2950  IF COUNT <  > 0 AND  LEFT$ (Q$,1) <  > "Y" THEN  GOTO 3020
2960  VTAB 23: INPUT "  ENTER THE NEW CARRYING CAPACITY: ";KK
2965  IF COUNT = 0 GOTO 2975
2970  IF KK > 160 OR KK <  = 0 THEN  HOME :PAUSE = 1000: GOSUB 5000: VTAB
   22: PRINT "    PLEASE CHOOSE A VALUE BETWEEN        1 AND 160.":PAUSE =
   3000: GOSUB 5000: HOME : GOTO 2940
2975  IF COUNT = 0 AND (KK > 160 OR KK <  = 110) THEN  GOSUB 4550: VTAB 22
   : PRINT "    PLEASE CHOOSE A VALUE BETWEEN        110 AND 160.":PAUSE =
   3000: GOSUB 5000: HOME : GOTO 2940
2980 K = KK
2990 COUNT = 1
3000  POKE  - 16304,0: POKE  - 16297,0
3010  GOTO 2710
3020 PAUSE = 500: GOSUB 5000
3030  REM
3040  REM    THE DIFFERENT POSSIBLE NUMBERS OF EQUILIBRIUM POINTS IS WORK
   ED WITH.
3050  REM
3060  HOME : HGR : TEXT
3070 PAUSE = 500: GOSUB 5000
3080  VTAB 10
```

```
3090  PRINT " * YOU'VE EXPERIMENTED WITH THE PREDATORCARRYING-CAPACITY AND
      SEEN ITS EFFECTS. YOU MAY ALSO HAVE NOTICED THAT THESE    GRAPHS NEE
     D NOT HAVE ALL THREE EQUILIB- RIUM POINTS."
3100  GOSUB 5200
3110  HCOLOR= 5:L$ = "PREY EATEN / TIME":X0 = 0:Y0 = 140: GOSUB 5450
3120 X0 = 1: GOSUB 5450
3130  HCOLOR= 3
3140  HPLOT 25,149
3150  FOR I = 0 TO 100
3160  HPLOT  TO X2(I),Y1(I)
3170  NEXT
3180  PRINT : PRINT
3190  PRINT "  BY CHANGING THE PREDATOR CARRYING    CAPACITY TRY TO COME
     UP WITH A SYSTEM   THAT HAS ONLY ONE EQUILIBRIUM POINT."
3200 PAUSE = 2000: GOSUB 5000
3210 K = 0
3220  GOSUB 5080: HOME :PAUSE = 500: GOSUB 5000
3230  POKE  - 16304,0: POKE  - 16297,0
3240  GOTO 3310
3250  REM

3260  REM     THE PREDATOR CARRYING CAPACITY IS CHANGED BY THE USER.
3270  REM

3280 PAUSE = 1000: GOSUB 5000
3290  VTAB 22
3300  PRINT " FORMER CARRYING CAPACITY = "K
3310 PAUSE = 1000: GOSUB 5000
3320  VTAB 24
3330  INPUT " ENTER A NEW CARRYING CAPACITY: ";KK
3340  IF KK > 160 OR KK <  = 0 THEN  HOME :PAUSE = 1000: GOSUB 5000: VTAB
     22: PRINT "    PLEASE CHOOSE A VALUE BETWEEN       1 AND 160.":PAUSE =
     3000: GOSUB 5000: HOME : GOTO 3280
3350 K = KK
3360  REM

3370  REM     POKE ORANGE COLOR.
3380  REM

3390  POKE 28,213
3400  HCOLOR= 5
3410  HPLOT 25,149
3420  FOR X = 0 TO 100
3430 Y = K * X ^ E / (X ^ E + DD)
3440  GOSUB 5610
3450  NEXT
3460  HOME
3470  REM
```

```
3480  REM      THE NUMBER OF EQUILIBRIUM POINTS IS CHECKED.
3490  REM
3500 PAUSE = 500: GOSUB 5000
3510  VTAB 22
3520  PRINT "  IS THERE ONLY ONE EQUILIBRIUM POINT?"
3530  INPUT Q$
3540  HOME : VTAB 22:PAUSE = 500: GOSUB 5000
3550  IF  LEFT$ (Q$,1) = "Y" AND K > 78 AND K < 128 THEN  PRINT "  THAT IS
      INCORRECT. THE SYSTEM HAS MORETHAN ONE EQUILIBRIUM POINT. PLEASE TRY
      AGAIN.":PAUSE = 1000: GOSUB 5000: GOSUB 5080: HOME : GOTO 3280
3560  IF  LEFT$ (Q$,1) <  > "Y" AND K > 78 AND K < 128 THEN  PRINT "  PLEA
     SE TRY ANOTHER CARRYING CAPACITY  TO GET ONLY ONE EQUILIBRIUM POINT."
     :PAUSE = 1000: GOSUB 5000: GOSUB 5080: HOME : GOTO 3280
3570  IF  LEFT$ (Q$,1) = "Y" AND (K <  = 78 OR K >  = 128) THEN  PRINT "
     THAT IS CORRECT. THIS SYSTEM HAS ONLY ONE EQUILIBRIUM POINT.":PAUSE =
     1000: GOSUB 5000: GOSUB 5080: HOME : GOTO 3590
3580  IF  LEFT$ (Q$,1) <  > "Y" AND (K <  = 78 OR K >  = 128) THEN  PRINT
     "  NO, YOU HAVE ONLY ONE EQUILIBRIUM     POINT.":PAUSE = 1000: GOSUB
     5000: GOSUB 5080: HOME
3590 PAUSE = 500: GOSUB 5000
3600  VTAB 22
3610  PRINT "  IS THIS EQUILIBRIUM POINT STABLE OR   UNSTABLE?"
3620  INPUT Q$
3630  HOME : VTAB 22:PAUSE = 500: GOSUB 5000
3640  IF  LEFT$ (Q$,1) = "S" THEN  PRINT "    THAT IS CORRECT."
3650  IF  LEFT$ (Q$,1) <  > "S" THEN  PRINT "    THAT IS INCORRECT."
3660 PAUSE = 1000: GOSUB 5000: VTAB 23
3670  PRINT "IT IS A STABLE EQUILIBRIUM POINT.":PAUSE = 1000: GOSUB 5000
3680  GOSUB 5080
3690  REM
3700  REM     THE NEXT SECTION OF THE MODULE IS SET UP.
3710  REM
3720  HOME : TEXT
3730  VTAB 22
3740  PRINT "  GOING BACK TO THE ORIGINAL GRAPH..."
3750 X = 26:Y = 0:XZ = 253:L = 148: GOSUB 5140
3760  HCOLOR= 3
3770  HPLOT 25,149
3780  FOR I = 0 TO 100
3790  HPLOT  TO X2(I),Y1(I)
3800  NEXT
3810  POKE  - 16304,0: POKE  - 16297,0
3820  REM
```

```
3830  REM     POKE ORANGE COLOR.
3840  REM

3850  POKE 28,213
3860  HCOLOR= 5
3870  HPLOT 25,149
3880  FOR I = 0 TO 100
3890  HPLOT  TO X2(I),Y2(I)
3900  NEXT
3910  REM

3920  REM     THE SUBPROGRAM PRED FUNCT2 IS RUN.
3930  REM

3940 D$ =  CHR$ (4)
3950  PRINT D$;"RUN PRED FUNCT2"
3960  END
3989  REM

3990  REM ******************
3991  REM *** SUBROUTINES ***
3992  REM ******************
4000  REM

4001  REM   SUBROUTINE TO FLASH SPACES BETWEEN CURVES.
4002  REM

4005  FOR T = 0 TO 21
4010 HC = HC + 3: IF HC > 3 THEN HC = 0
4020  HCOLOR= HC
4030  FOR I = A TO B STEP ST
4040  HPLOT X2(I),Y1(I) TO X2(I),Y2(I)
4050  NEXT
4060  NEXT
4070  RETURN
4100  REM

4101  REM   SUBROUTINE THAT ALTERNATELY COLORS AND DARKENS SPACES BETWEEN
     TWO CURVES.
4102  REM

4105 H1 = 3:H2 = 3:H3 = 3:H4 = 3
4110 CA = 0:CB = 0:CC = 0:CD = 0
4120 HC = 3
4130  FOR I = 1 TO LG
4150 CA = CA + 1:CB = CB + 1:CC = CC + 1:CD = CD + 1
4151  IF CA > YS AND H1 = 0 AND LG - I <  = YS THEN  GOTO 4183
4160  IF CA > YS THEN CA = 0:H1 = H1 + 3: IF  PEEK ( - 16384) = 141 THEN H
     1 = 0
4165  IF H1 > 3 THEN H1 = 0
```

```
4170  HCOLOR= H1
4180  HPLOT X2(CA),Y1(CA) TO X2(CA),Y2(CA)
4183  IF CB > YU - YS AND H2 = 0 AND LG - I <  = YU - YS THEN  GOTO 4300
4190  IF CB > YU - YS THEN CB = 0:H2 = H2 + 3: IF  PEEK ( - 16384) = 141 THEN
     H2 = 0
4195  IF H2 > 3 THEN H2 = 0
4200  HCOLOR= H2
4210  HPLOT X2(YU - CB),Y1(YU - CB) TO X2(YU - CB),Y2(YU - CB)
4220  IF CE <  > 0 GOTO 4300
4230  IF CC > YE - YU THEN CC = 0:H3 = H3 + 3: IF  PEEK ( - 16384) = 141 THEN
     H3 = 0
4235  IF H3 > 3 THEN H3 = 0
4240  HCOLOR= H3
4250  HPLOT X2(YU + CC),Y1(YU + CC) TO X2(YU + CC),Y2(YU + CC)
4260  IF CD > 101 - YE THEN CD = 0:H4 = H4 + 3: IF  PEEK ( - 16384) = 141 THEN
     H4 = 0
4265  IF H4 > 3 THEN H4 = 0
4270  HCOLOR= H4
4280  HPLOT X2(101 - CD),Y1(101 - CD) TO X2(101 - CD),Y2(101 - CD)
4295  IF  PEEK ( - 16384) = 141 THEN  GOTO 2420
4300  NEXT
4310  RETURN
4500  REM

4510  REM      PAUSE, RETURN, PAUSE, VTAB SUBROUTINE.
4520  REM

4530  GOSUB 5000
4540  GOSUB 5080
4550  HOME
4560 PAUSE = 500: GOSUB 5000
4570  VTAB 21
4580  RETURN
5000  REM

5010  REM      PAUSE SUBROUTINE.
5020  REM      VARIABLES TO BE PROVIDED:
5030  REM      D  = LENGTH OF PAUSE.
5040  REM

5050  FOR PS = 1 TO PAUSE
5060  NEXT
5070  RETURN
5080  REM

5090  REM      PRESS -RETURN- SUBROUTINE.
5100  REM

5105  POKE  - 16368,0
5110  VTAB 24
5120  INPUT "            PRESS -RETURN- TO CONTINUE";Q$
5130  RETURN
```

```
5140  REM

5150  REM     SUBROUTINE THAT BLACKS OUT A RECTANGLE ON THE HGR SCREEN.
5160  REM -VARIABLES THAT MUST BE PROVIDED-
5170  REM     X = STARTING X COORDINATE
5180  REM     Y = STARTING Y COORDINATE
5190  REM     XZ = LENGTH OF RECTANGLE ALONG THE X AXIS.
5200  REM     L = WIDTH OF RECTANGLE ALONG THE Y AXIS.
5210  REM

5220  HCOLOR= 0
5230  FOR TA = 0 TO L
5240  HPLOT X,TA + Y TO X + XZ,TA + Y
5250  NEXT TA
5260  HCOLOR= 3
5270  RETURN
5271  REM

5280  REM  AXES AND UNITS FOR GRAPHS
5290  REM   SUBROUTINE DEVELOPED BY J. SPAIN,MICHIGAN TECH UNIV.,AND B.J.
    HINKEL,ALBION COLLEGE
5300  REM   DEFINE X$=VARIABLE PLOTTED ON X AXIS
5310  REM  DEFINE Y$=VARIABLE PLOTTED ON Y AXIS
5320  REM   DEFINE YM =MAXIMUM UNITS ON THE Y AXIS
5330  REM  DEFINE XM = MAXIMUM UNITS ON THE X AXIS
5335  REM

5340  HCOLOR= 3: SCALE= 1:SC = 1: ROT= 0
5350  REM   LIST OF RESERVED VARIABLES:X,X0,XM,X$,Y,Y0,YM,Y$,Z,ZF,Z0,Z3,L$
    ,SC
5360  HPLOT 23,0 TO 23,149
5370  HPLOT 25,149 TO 279,149
5380  REM  WRITE VARIABLE NAME ON X-AXIS
5390 Z0 = 0:L$ = X$:X0 = 60:Y0 = 150
5400  GOSUB 5450
5410  REM  WRITE VARIABLE NAME ON Y-AXIS
5420 Z0 = 1:L$ = Y$:X0 = 10:Y0 = 140
5425 X0 = 13
5430  GOSUB 5450
5440  RETURN
5450  REM  ALPHANUMERIC CHARACTERS FOR HGR
5460  REM  THE FOLLOWING MUST BE DEFINED
5470  REM  BEFORE ENTERING THE SUBROUTINE
5480  REM  L$ = "CHARACTER STRING"
5490  REM  Y0 = THE INITIAL Y POSITION
5500  REM  X0 = THE INITIAL X POSITION
5510  REM  SET Z0 = 0 IF PRINTING HORIZONTAL
5520  REM  SET Z0 = 1 IF PRINTING VERTICALLY
5530  FOR Z = 1 TO  LEN (L$):Z3 =  ASC ( MID$ (L$,Z,1))
5540  IF Z0 <  > 0 THEN  GOTO 5570
5550  IF Z3 > 64 THEN  DRAW Z3 - 64 AT X0 + (Z - 1) * 7 * SC,Y0: GOTO 5590
```

```
5560  DRAW Z3 AT X0 + (Z - 1) * 7 * SC,Y0: GOTO 5590
5570  ROT= 48: IF Z3 > 64 THEN  DRAW Z3 - 64 AT X0,Y0 - (Z - 1) * 7: GOTO
     5590
5580  DRAW Z3 AT X0,Y0 - (Z - 1) * 7
5590  ROT= 0: NEXT Z
5600  RETURN
5605  REM
5610  REM  SCALE AND PLOT POINT FOR DEFINED X AND Y
5620  REM  FOR LINE PLOT MAKE ZF=1
5625  REM
5630 X0 = 23 + X * 256 / XM
5640 Y0 = 149 - Y * 140 / YM
5650  IF X0 > 279 OR X0 < 0 OR Y0 > 149 OR Y0 < 0 THEN  GOTO 5680
5660  IF Z6 = 1 THEN  HPLOT  TO X0,Y0: GOTO 5680
5670  HPLOT X0,Y0: IF ZF = 1 THEN Z6 = 1
5680  RETURN
9995  REM
9996  REM    DATA STATEMENTS CONTAINING THE PREY RECRUITMENT X AND Y POIN
     TS AND THE PREDATOR Y POINTS TO BE PLOTTED.
9997  REM
10000  DATA  23,149,149,25,144,148,28,139,147
10010  DATA  30,135,143,33,131,139,35,126,132
10020  DATA  38,122,125,40,118,118,43,114,110
10030  DATA  46,110,103,48,107,96,51,103,90
10040  DATA  53,99,84,56,96,80,58,92,76
10050  DATA  61,89,72,63,86,69,66,83,66
10060  DATA  69,80,64,71,77,62,74,74,61
10070  DATA  76,71,59,79,68,58,81,66,57
10080  DATA  84,63,56,87,61,55,89,59,54
10090  DATA  92,57,53,94,54,53,97,52,52
10100  DATA  99,51,52,102,49,51,104,47,51
10110  DATA  107,45,51,110,44,50,112,42,50
10120  DATA  115,41,50,117,40,49,120,39,49
10130  DATA  122,37,49,125,37,49,127,36,49
10140  DATA  130,35,48,133,34,48,135,34,48
10150  DATA  138,33,48,140,33,48,143,32,48
10160  DATA  145,32,48,148,32,48,151,32,48
10170  DATA  153,32,47,156,32,47,158,32,47
10180  DATA  161,33,47,163,33,47,166,34,47
10190  DATA  168,34,47,171,35,47,174,36,47
10200  DATA  176,37,47,179,37,47,181,39,47
10210  DATA  184,40,47,186,41,47,189,42,47
10220  DATA  191,44,47,194,45,47,197,47,47
10230  DATA  199,49,47,202,50,47,204,52,47
10240  DATA  207,54,47,209,57,47,212,59,46
```

```
10250 DATA 215,61,46,217,63,46,220,66,46
10260 DATA 222,68,46,225,71,46,227,74,46
10270 DATA 230,77,46,232,80,46,235 83 46
10280 DATA 238,86,46,240,89,46 243 92 46
10290 DATA 245,96,46,248,99,46 250 103 46
10300 DATA 253,106,46,255,110, 46 258 114 46
10310 DATA 261,118,46,263,122, 46 26[illegible]26 46
10320 DATA 268,131,46,271,135, 46 273 139 46
10330 DATA 276,144,46,279,149,46
```

```
5  REM  PRED FUNCT2
10  REM     PRED FUNCT2 IS A SUBPROGRAM OF PREDATOR FUNCTIONAL RESPONSE.
15  REM     PROGRAMMED BY  MARK SHALTZ
20  REM  THIS PROGRAM HAS DEVELPED BY THE SUMIT I COURSEWARE DEVELOPMENT P
    ROJECT, DEPARTMENT OF BIOLOGICAL SCIENCES, MICHIGAN TECHNOLOGICAL UNI
    VERSIY, HOUGHTON, MI 49931.
25  REM  THIS MATERIAL IS BASED UPON WORK SUPPORTED BY THE NATIONAL SCIENC
    E FOUNDATION UNDER GRANT NUMBER SED-7919051.
30  REM  ANY OPINIONS, FINDINGS, AND CONCLUSIONS OR RECOMMENDATIONS EXPRES
    SED IN THIS PUBLICATION ARE THOSE OF THE AUTHORS AND DO NOT NECESSARI
    LY REFLECT THE VIEWS OF THE NATIONAL SCIENCE FOUNDATION.
100  DIM Y1(201),X2(201),Y2(201)
110  HOME
120  HCOLOR= 3
130 X$ = "DENSITY OF PREY POPULATION"
140 Y$ = "CHANGE IN DENSITY/YR"
150  REM
160  REM     A CHANGE IN SCALING IS INTRODUCED.
170  REM
180  GOSUB 4050
210  PRINT "  FOR THE NEXT DEMONSTRATION IT MIGHT BEBETTER TO LOOK ONLY AT
     ONE OF THE TWO  STABLE EQUILIBRIUM POINTS."
220 PAUSE = 3000: GOSUB 4000
260  VTAB 22
270  PRINT "  SO WE'LL IGNORE EVERYTHING TO THE      RIGHT OF THE DOTTED LI
     NE..."
280  HPLOT 126,0
290  FOR I = 0 TO 148
300  HCOLOR= 0: IF  INT (I / 2) = I / 2 THEN  HCOLOR= 3
310  HPLOT 126,I
320  NEXT
330 PAUSE = 1000: GOSUB 5000
340 X = 127:Y = 0:XZ = 152:L = 148: GOSUB 5140
350 PAUSE = 3000: GOSUB 5000
360  GOSUB 4050
380  VTAB 22
390  PRINT "  WHAT REMAINS IS PUT ON A LARGER SCALE SO IT CAN BE EXAMINED
     MORE CLOSELY."
400  TEXT
410 X = 25:Y = 0:XZ = 102:L = 148: GOSUB 5140
420  POKE  - 16304,0: POKE  - 16297,0
430 ZF = 1
440  VTAB 22
450  HPLOT 25,149
460 XM = 40
470 YM = .225
480 PAUSE = 1000: GOSUB 5000
490  POKE  - 16304,0: POKE  - 16297,0
500  REM
```

```
510  REM     THE PREY RECRUITMENT CURVE IS DRAWN.
520  REM

530 R = .01
540 K = 100
550  FOR X = 0 TO XM STEP .5
560 Y = R * X * (1 - X / K)
570  IF Y < 0 THEN Y = 0
580  GOSUB 5610
590 Y1(X) = Y0
600  NEXT
610  REM

620  REM     PREDATOR RESPONSE IS PLOTTED.
630  REM

640 YM = 112.5
650  HCOLOR= 5
660  HPLOT 25,149
670 K = 110
680 E = 2.5
690 DD = 300
700 YS = 0:YU = 0:YE = 0
710  VTAB 22
720  FOR X = 0 TO XM STEP .5
730 Y = K * X ^ E / (X ^ E + DD)
740  GOSUB 5610
750 X2(X) = X0:Y2(X) = Y0
760  NEXT
770 PAUSE = 1000: GOSUB 5000: GOSUB 5080
780  REM

790  REM     THE CONCEPT OF SUBTRACTING CURVES IS INTRODUCED.
800  REM

810  TEXT : GOSUB 4050
820  VTAB 5
830  PRINT "    YOU WILL RECALL THAT THE PREY RE-   CRUITMENT CURVE REPRES
     ENTS THE POSITIVE CHANGE IN THE PREY POPULATION, AND THE  PREDATOR FU
     NCTIONAL RESPONSE CURVE     REPRESENTS THE NEGATIVE CHANGE."
840 PAUSE = 1000: GOSUB 5000
850  VTAB 11
860  PRINT "    IF THIS IS SO, THEN THE DIFFERENCE  BETWEEN THESE TWO CURV
     ES IS THE CHANGE  IN PREY DENSITY PER SOME TIME INTERVAL."
870 PAUSE = 1000: GOSUB 5000
880  VTAB 15
890  PRINT "    SO THE RELATIVE AMOUNT OF TIME      NECESSARY FOR THE PREY
      DENSITY TO REACH A STABLE EQUILIBRIUM POINT CAN BE        ESTIMATED."
```

```
900 PAUSE = 1000: GOSUB 5000
910  VTAB 20
920  PRINT "(THE PRECISE LENGTH OF TIME CANNOT BE   CALCULATED DUE TO SCAL
     E DIFFERENCES.)"
930 PAUSE = 500: GOSUB 4000
970  POKE - 16304,0: POKE - 16297,0
990  REM

1000  REM    SIMULATION THAT SUBTRACTS THE TWO CURVES AND TAKES THIS DIFF
      ERENCE FROM THE X-AXIS.
1010  REM

1020 COUNT = 0
1030 I = 18
1040  GOTO 1240
1050  IF X2(I) < > X2(J) THEN COUNT = COUNT + 1
1060 TP = Y1(I)
1070  IF Y1(I) < Y2(I) THEN TP = Y2(I)
1080  FOR H = 148 TO  INT (TP) STEP - 1
1090  HCOLOR= 0: IF  INT (H / 3) = H / 3 THEN  HCOLOR= 3
1100  HPLOT X2(I),YY TO X2(I),H
1110 YY = H
1120  NEXT
1130  HCOLOR= 3
1140  HPLOT X2(I),Y1(I) TO X2(I),Y2(I)
1150  HPLOT X2(I) - 2,Y1(I) TO X2(I) - 2,Y2(I)
1160  HCOLOR= 0
1170  HPLOT X2(I),147 TO X2(I),Y1(I)
1180  HPLOT X2(J),Y1(J) TO X2(J),Y2(J)
1190  HPLOT X2(J) - 2,Y1(J) TO X2(J) - 2,Y2(J)
1200  HPLOT X2(J),Y1(J) TO X2(J),148
1210  HPLOT X2(J),148 TO X2(I),148
1220  HPLOT X2(J),147 TO X2(I),147
1230  IF X2(J) = X2(I) THEN COUNT = COUNT + 3
1240  IF COUNT < 2 THEN  GOSUB 4050
1250  IF COUNT < 2 AND CT = 0 THEN  PRINT " THE DIFFERENCE BETWEEN THE TWO
      CURVES  IS THE EFFECT OF PREDATION ON THE PREY  DENSITY PER TIME INT
      ERVAL.":PAUSE = 4000: GOSUB 5000
1260  HCOLOR= 3
1270  HPLOT X2(I),Y1(I) TO X2(I),Y2(I)
1280  HPLOT X2(I) - 2,Y1(I) TO X2(I) - 2,Y2(I)
1290  IF COUNT = 0 AND CT = 0 THEN  GOSUB 5080
1300  IF COUNT < 2 THEN  HOME
1310 YY = Y1(I)
1320  VTAB 21
1330  IF COUNT < 2 AND CT = 0 THEN  PRINT " BY SUBTRACTING THIS DIFFERENCE
      FROM THEX-AXIS, THE PREY DENSITY FOR THE         FOLLOWING TIME INTER
      VAL IS OBTAINED.":PAUSE = 2000: GOSUB 5000
1340 TP = Y1(I)
1350  IF Y1(I) < Y2(I) THEN TP = Y2(I)
1360  FOR H =  INT (TP) TO 148
```

```
1370  HCOLOR= 0: IF  INT (H / 3) = H / 3 THEN  HCOLOR= 3
1380  HPLOT X2(I),YY TO X2(I),H
1390 YY = H
1400  NEXT
1410  IF X2(J) = X2(I) THEN COUNT = COUNT - 3
1420 J = I
1430 XX = X2(I) - (Y1(I) - Y2(I))
1440 I = (XX - 23) * XM / 256
1450  HCOLOR= 3
1460  IF X2(I) < 279 AND X2(I) > 0 GOTO 1530
1470  HPLOT X2(J),148 TO 279,148
1480  HPLOT X2(J),147 TO 279,147
1490  GOSUB 4050
1500  PRINT "  PREY DENSITY HAS GONE OFF THE GRAPH  TOWARD THE OTHER EQUI
LIBRIUM POINT."
1510 PAUSE = 2000: GOSUB 5000: GOSUB 5080
1512  HCOLOR= 0
1513  HPLOT X2(J),148 TO 279,148
1514  HPLOT X2(J),147 TO 279,147
1515  HCOLOR= 3
1520  HOME : GOTO 1890
1530  HPLOT X2(J),148 TO X2(I),148
1540  HPLOT X2(J),147 TO X2(I),147
1550  IF COUNT = 0 AND CT = 0 THEN  GOSUB 5080: HOME
1560  IF X2(I) = X2(J) GOTO 1590
1570  GOTO 1050
1580  REM

1590  HOME
1600  VTAB 21
1601  IF I >  = 28 AND I < 31 THEN  HOME : VTAB 21: PRINT "NOTICE THAT THE
      PREY DENSITY IS ON THE  UNSTABLE EQUILIBRIUM POINT. TRY A DEN-  SITY
      JUST OFF THIS POINT.": GOSUB 5080: HOME : GOTO 1930
1602  IF CHECK > 0 GOTO 1610
1605  IF COUNT > 0 AND CT > 0 THEN COUNT = COUNT - 1
1610  PRINT "  IT TOOK ";COUNT;" TIME INTERVALS FOR"
1615 CHECK = 1
1620  VTAB 22
1630  PRINT "THE PREY DENSITY TO REACH EQUILIBRIUM."
1640  VTAB 23
1650  PRINT "                   PRESS -RETURN- TO CONTINUE"
1670  IF  PEEK ( - 16384) = 141 THEN  GOTO 1690
1680  GOTO 1050
1690  HCOLOR= 3: HPLOT 23,149: FOR I = 0 TO 40 STEP .5
1700  IF I >  = 40 GOTO 1730
1710  HPLOT  TO X2(I),Y1(I)
1720  NEXT
1730  HCOLOR= 5: HPLOT 23,149
1740  FOR I = 0 TO 40 STEP .5
1750  HPLOT  TO X2(I),Y2(I)
1760  IF I > 40 GOTO 1780
1770  NEXT
```

```
1780  HOME :CT = CT + 1: IF CT < > 1 GOTO 1890
1790  REM
1800  REM    THE SIMULATION IS REPEATED WITH A NEW STARTING PREY DENSITY
      (INPUT BY THE USER).
1810  REM
1820  GOSUB 4060
1840  PRINT "    TRY A DIFFERENT STARTING PREY      DENSITY TO COMPARE WI
      TH THE ORIGINAL    EXAMPLE."
1850  POKE - 16368,0
1860 PAUSE = 1000: GOSUB 5000: VTAB 24: INPUT "    PRESS -RETURN- TO INPUT
      NEW DENSITY";Q$
1870  HOME : POKE - 16304,0: POKE  - 16297,0
1880  GOTO 1940
1890  VTAB 22:PAUSE = 1000: GOSUB 5000
1900  IF PEEK ( - 16384) < > 0 THEN  POKE  - 16368,0
1910  INPUT "  WOULD YOU LIKE TO TRY AGAIN FROM      ANOTHER STARTING PREY
      DENSITY?";Q$
1920  IF LEFT$ (Q$,1) <  > "Y" GOTO 2040
1930  GOSUB 4050
1940  VTAB 22
1960  PRINT "  WHERE WOULD YOU LIKE TO START? (1-35) "
1970  PRINT : INPUT I
1980  IF I > 35 OR I < 1 THEN  HOME :PAUSE = 1000: GOSUB 5000: VTAB 22: PRINT
      "PLEASE CHOOSE A VALUE BETWEEN 1 AND 35.":PAUSE = 3000: GOSUB 5000: GOTO
      1930
1990 COUNT = 0:CHECK = 0
2000  GOTO 1050
2010  REM
2020  REM     THE CONCEPT OF ADDITIONAL PARAMETERS IS BROUGHT UP.
2030  REM
2040  HOME : HGR : TEXT
2050 PAUSE = 1000: GOSUB 5000: VTAB 10
2060  PRINT "    FROM THE PREVIOUS SIMULATIONS YOU   SAW THAT THERE EXISTS
      A RELATIONSHIP    BETWEEN THE PREY RECRUITMENT AND THE    PREDATOR F
      UNCTIONAL RESPONSE CURVE."
2070 PAUSE = 1000: GOSUB 5000
2080  VTAB 15
2090  PRINT "    NEXT YOU WILL SEE THAT A CHANGE IN  A SINGLE PARAMETER CA
      N AFFECT THE ENTIRESYSTEM."
2100  REM
2110  REM     THE SUBPROGRAM PRED FUNCT3 IS RUN.
2120  REM
2130 D$ =  CHR$ (4)
2140  PRINT D$;"RUN PRED FUNCT3"
4000  REM
```

```
4010  REM     PAUSE, RETURN, HOME, VTAB SUBROUTINE.
4020  REM

4030  GOSUB 5000
4040  GOSUB 5080
4050  HOME
4060 PAUSE = 500: GOSUB 5000
4070  VTAB 21
4080  RETURN
4090  REM

4995  REM

4996  REM ************************
4997  REM **** SUBROUTINES ******
4998  REM ************************
4999  REM

5000  REM
5010  REM     PAUSE SUBROUTINE.
5020  REM     VARIABLES TO BE PROVIDED:
5030  REM       PAUSE  = LENGTH OF PAUSE.
5040  REM

5050  FOR PS = 1 TO PAUSE
5060  NEXT
5070  RETURN
5080  REM

5090  REM     PRESS -RETURN- SUBROUTINE.
5100  REM

5105  POKE  - 16368,0
5110  VTAB 24
5120  INPUT "            PRESS -RETURN- TO CONTINUE";Q$
5130  RETURN
5140  REM

5150  REM     SUBROUTINE THAT BLACKS OUT A RECTANGLE ON THE HGR SCREEN.
5160  REM -VARIABLES THAT MUST BE PROVIDED-
5170  REM     X = STARTING X COORDINATE
5180  REM     Y = STARTING Y COORDINATE
5190  REM     XZ = LENGTH OF RECTANGLE ALONG THE X AXIS.
5200  REM     L = WIDTH OF RECTANGLE ALONG THE Y AXIS.
5210  REM

5220  HCOLOR= 0
5230  FOR TA = 0 TO L
5240  HPLOT X,TA + Y TO X + XZ,TA + Y
5250  NEXT TA
```

```
5260  HCOLOR= 3
5270  RETURN
5275  REM
5280  REM  AXES AND UNITS FOR GRAPHS
5290  REM  SUBROUTINE DEVELOPED BY J. SPAIN,MICHIGAN TECH UNIV.,AND B.J.
WINKEL,ALBION COLLEGE
5300  REM  DEFINE X$=VARIABLE PLOTTED ON X AXIS
5310  REM  DEFINE Y$=VARIABLE PLOTTED ON Y AXIS
5320  REM  DEFINE YM =MAXIMUM UNITS ON THE Y AXIS
5330  REM  DEFINE XM = MAXIMUM UNITS ON THE X AXIS
5335  REM
5340  HCOLOR= 3: SCALE= 1:SC = 1: ROT= 0
5350  REM  LIST OF RESERVED VARIABLES:X,X0,XM,X$,Y,Y0,YM,Y$,Z,ZF,Z0,Z3,L$
,SC
5360  HPLOT 23,0 TO 23,149
5370  HPLOT 25,149 TO 279,149
5380  REM  WRITE VARIABLE NAME ON X-AXIS
5390 Z0 = 0:L$ = X$:X0 = 60:Y0 = 150
5400  GOSUB 5450
5410  REM  WRITE VARIABLE NAME ON Y-AXIS
5420 Z0 = 1:L$ = Y$:X0 = 10:Y0 = 140
5430  GOSUB 5450
5440  RETURN
5450  REM  ALPHANUMERIC CHARACTERS FOR HGR
5460  REM  THE FOLLOWING MUST BE DEFINED
5470  REM  BEFORE ENTERING THE SUBROUTINE
5480  REM  L$ = "CHARACTER STRING"
5490  REM  Y0 = THE INITIAL Y POSITION
5500  REM  X0 = THE INITIAL X POSITION
5510  REM  SET Z0 = 0 IF PRINTING HORIZONTAL
5520  REM  SET Z0 = 1 IF PRINTING VERTICALLY
5530  FOR Z = 1 TO  LEN (L$):Z3 =  ASC ( MID$ (L$,Z,1))
5540  IF Z0 < > 0 THEN  GOTO 5570
5550  IF Z3 > 64 THEN  DRAW Z3 - 64 AT X0 + (Z - 1) * 7 * SC,Y0: GOTO 5590
```

```
5560 DRAW Z3 AT X0 + (Z - 1) * 7 * SC,Y0: GOTO 5590
5570 ROT= 48: IF Z3 > 64 THEN DRAW Z3 - 64 AT X0,Y0 - (Z - 1) * 7: GOTO
     5590
5580 DRAW Z3 AT X0,Y0 - (Z - 1) * 7
5590 ROT= 0: NEXT Z
5600 RETURN
5605 REM
5610 REM SCALE AND PLOT POINT FOR DEFINED X AND Y
5620 REM FOR LINE PLOT MAKE ZF=1
5625 REM
5630 X0 = 23 + X * 256 / XM
5640 Y0 = 149 - Y * 140 / YM
5650 IF X0 > 279 OR X0 < 0 OR Y0 > 149 OR Y0 < 0 THEN GOTO 5680
5660 IF ZG = 1 THEN HPLOT TO X0,Y0: GOTO 5680
5670 HPLOT X0,Y0: IF ZF = 1 THEN ZG = 1
5680 RETURN
```

```
5 REM   PRED FUNCT3
10 REM    PRED FUNCT3 IS A SUBPROGRAM OF PREDATOR FUNCTIONAL RESPONSE.
12 REM    PROGRAMMED BY MARK SHALTZ
15 REM  THIS PROGRAM WAS DEVELOPED BY THE SUMIT I COURSEWARE DEVELOPMENT
    PROJECT, DEPARTMENT OF BIOLOGICAL SCIENCES, MICHIGAN TECHNOLOGICAL UN
    IVERSITY, HOUGHTON, MI 49931.
20 REM  THIS MATERIAL IS BASED UPON WORK SUPPORTED BY THE NATIONAL SCIENC
    E FOUNDATION UNDER GRANT NUMBER SED-7919051.
25 REM   ANY OPINIONS, FINDINGS, AND CONCLUSIONS OR RECOMMENDATIONS EXPRE
    SSED IN THIS PUBLICATION ARE THOSE OF THE AUTHORS AND DO NOT NECESSAR
    ILY REFLECT THE VIEWS OF THE NATIONAL SCIENCE FOUNDATION.
100 DIM Y1(101),X2(101),Y2(101)
110 X$ = "DENSITY OF PREY POPULATION"
120 Y$ = "PREY GROWTH / TIME"
130 REM
140 REM    HUNTER PRESSURE IS INTRODUCED AS A PARAMETER.
150 REM
160 PAUSE = 1: GOSUB 4000
170 PAUSE = 500: GOSUB 5000
180 VTAB 7
190 PRINT "    THE PREY RECRUITMENT CURVE IS THE   RESULT OF PREY BIRTHS
    MINUS NON-PREDATORDEATHS AT DIFFERENT PREY DENSITIES."
200 PAUSE = 500: GOSUB 5000
210 HCOLOR= 5:Z0 = 1
220 L$ = "PREY EATEN / TIME":X0 = 0:Y0 = 140: GOSUB 5450
230 X0 = 1: GOSUB 5450
240 HCOLOR= 3
250 VTAB 11
260 PRINT "    IF THE PREY ARE ALSO HARVESTED BY   MAN, THEN YOU MUST CON
    SIDER AN AD-      DITIONAL EFFECT ON PREY RECRUITMENT,   THAT OF HUN
    TING PRESSURE."
270 GOSUB 5280
280 PRINT : PRINT "    HUNTING PRESSURE LOWERS THE PREY    RECRUITMENT CU
    RVE."
290 PAUSE = 500: GOSUB 5000
300 VTAB 20
310 PRINT "    LET'S EXAMINE HOW THIS HAPPENS."
320 PAUSE = 500: GOSUB 4000
330 VTAB 22
340 PRINT "  FIRST WE MUST AGAIN GO BACK TO THE    ORIGINAL PREY RECRUITM
    ENT CURVE."
350 PAUSE = 1000: GOSUB 5000
360 POKE - 16304,0: POKE - 16297,0
370 REM
```

```
380  REM       THE PREY RECRUITMENT CURVE IS PLOTTED.
390  REM

400 ZF = 1
410 XM = 100:YM = .3
420  HPLOT 23,149
430  FOR I = 0 TO 100
440  READ X2(I),Y1(I),Y2(I)
450  HPLOT  TO X2(I),Y1(I)
460  NEXT
470 PAUSE = 1000: GOSUB 5000: HOME : GOSUB 5000
480  VTAB 21
490  PRINT "  IT HAS BEEN FOUND THAT PREY LOSS DUE  TO HUNTING IS A LINEAR
      FUNCTION OF PREY DENSITY."
500  REM

510  REM       HUNTER PRESSURE IS PLOTTED.
520  REM

530  REM       POKE ORANGE COLOR.
540  POKE 28,213
550  HCOLOR= 5
560  HPLOT 23,149
570 HP = .05
580  FOR N = 0 TO 100
590 X = N:Y = .25 * HP / 50 * 2 * N
600  GOSUB 5610
610  NEXT
620 PAUSE = 500: GOSUB 4000
630  PRINT "  THIS MEANS THAT HUNTERS TEND TO        HARVEST A CERTAIN PERC
      ENTAGE OF THE     PREY, REGARDLESS OF PREY DENSITY."
640 PAUSE = 500: GOSUB 4000
650  REM

660  REM      THE CONCEPT OF POSITIVE AND NEGATIVE CURVES IS APPLIED TO PRE
     Y RECRUITMENT AND HUNTER PRESSURE.
670  REM

680  TEXT :PAUSE = 500: GOSUB 5000
690  VTAB 7
700  PRINT "   THE PREY RECRUITMENT CURVE REPRESENTSPREY ADDED TO THE POPU
     LATION, AND THE   HUNTING LINE REPRESENTS PREY KILLED."
710 PAUSE = 500: GOSUB 5000
720  VTAB 11
730  PRINT "    BY SUBTRACTING PREY KILLED DUE TO   HUNTING FROM PREY ADDE
     D THROUGH RECRUIT-MENT, A NEW CURVE WOULD RESULT."
740 PAUSE = 500: GOSUB 5000: VTAB 15
750  PRINT "    THIS NEW PREY RECRUITMENT CURVE     WOULD TAKE INTO ACCOUN
     T HUNTER PRESSURE."
760 PAUSE = 500: GOSUB 4000
770  POKE  - 16304,0: POKE  - 16297,0
780  REM
```

```
790  REM     THE TWO CURVES ARE SUBTRACTED.
800  REM

810 PAUSE = 500: GOSUB 5000
820  VTAB 22
830  PRINT "    SUBTRACTING THE CURVES..."
840 HP = .05:HC = 6:FLAG = 0: GOSUB 4100
850 PAUSE = 1000: GOSUB 5000: GOSUB 4050
860  VTAB 22
870  PRINT "  THUS THE PREY RECRUITMENT CURVE IS    LOWERED BY HUNTING PRE
     SSURE."
880 PAUSE = 500: GOSUB 4000
890  REM

900  REM     THE PREDATOR FUNCTIONAL RESPONSE CURVE IS PLOTTED.
910  REM

920  VTAB 22
930  PRINT "  THE PREDATOR FUNCTIONAL RESPONSE CURVEIS NOT AFFECTED BY HUN
     TING PRESSURE."
940  HCOLOR= 5
950  HPLOT 23,149
960  FOR I = 0 TO 100
970  HPLOT  TO X2(I),Y2(I)
980  NEXT
990 PAUSE = 500: GOSUB 4000
1000  REM

1010  REM     A HYPOTHETICAL SITUATION IS SET UP.
1020  REM

1030  TEXT
1040 PAUSE = 500: GOSUB 5000
1050  VTAB 12
1060  PRINT "    TO STUDY THE POSSIBLE CONSEQUENCES  OF HUNTING PRESSURE O
      N A SYSTEM, LET'S  LOOK AT A HYPOTHETICAL SITUATION."
1070 X = 24:Y = 0:XZ = 255:L = 148: GOSUB 5140
1080  HCOLOR= 3
1090  HPLOT 23,149
1100  FOR I = 0 TO 100
1110  HPLOT  TO X2(I),Y1(I)
1120  NEXT
1130 PAUSE = 1: GOSUB 4000
1140  VTAB 7
1150  PRINT "    IF YOU WERE A WILDLIFE MANAGER, ONE OF YOUR CONCERNS MAY
      BE THAT OF KEEPING A HIGH PREY POPULATION AVAILABLE FOR    HUNTING EA
      CH YEAR."
1160  HCOLOR= 5
1170  HPLOT 23,149
1180  FOR I = 0 TO 100
1190  HPLOT  TO X2(I),Y2(I)
1200  NEXT
```

```
1210  REM

1220  REM     THE HUNTER PRESSURE IS INPUT BY THE USER.
1230  REM

1240  VTAB 12
1250  PRINT "     YOU ARE MANAGING AN AREA WITH        10,000 PREY. HOW MANY
      OF THESE PREY     WOULD YOU ALLOW TO BE HARVESTED           BY HUNTERS
     ?"
1260  PRINT : PRINT : INPUT HP
1270 HP =  INT (HP + .5)
1280 PAUSE = 1: GOSUB 4050
1290  VTAB 2
1300  PRINT "     YOU CHOSE ";HP;" PREY TO BE"
1310  PRINT "HARVESTED."
1320  IF HP < 100 THEN  VTAB 15: PRINT "     BY ALLOWING SO FEW TO BE HARVE
     STED, YOUR AREA'S TOWNS COULD LOSE VALUABLE   INCOME DUE TO THE LACK
     OF HUNTERS. TRY ALARGER NUMBER."
1330  IF HP > 600 THEN  VTAB 7: PRINT "   KILLING THAT MANY COULD STRAIN T
     HE   PREY POPULATION. TRY A SMALLER NUMBER."
1340  IF HP >  = 100 AND HP <  = 600 THEN  VTAB 11: PRINT "     LET'S SEE T
     HE EFFECT OF HUNTERS     HARVESTING ";HP;" PREY."
1350 PAUSE = 4000: GOSUB 5000
1360  IF HP < 100 OR HP > 600 THEN PAUSE = 1: GOSUB 4000: GOTO 1240
1370  POKE  - 16304,0: POKE  - 16297,0
1380  VTAB 22
1390 PAUSE = 500: GOSUB 5000
1400  VTAB 22
1410  PRINT "  THE PREY DENSITY IN YOUR AREA IS AT  THE UPPER STABLE EQUI
     LIBRIUM POINT."
1420  FOR I = 1 TO 12
1430  HCOLOR= 3: IF  INT (I / 2) <  > I / 2 THEN  HCOLOR= 0
1440 PAUSE = 500: GOSUB 5000
1450  HPLOT [illegible]0,37 TO 200,45 TO 206,39
1460  NEXT
1470 PAUSE = 500: GOSUB 5000
1480  GOSUB 4050
1490  REM

1500  REM     THE PREY RECRUITMENT CURVE IS LOWERED TO ACCOUNT FOR HUNTER
     PRESSURE.
1510  REM

1520  VTAB 22
1530  PRINT "  BY KILLING ";HP;" PREY, THE PREY"
1540 HTEMP = HP / 10000
1550  PRINT "RECRUITMENT CURVE IS MOVED DOWN."
1560 HP = HP / 10000:HC = 3:FLAG = 1: GOSUB 4100
1570 HO = HTEMP
1580  GOSUB 4400
1590 PAUSE = 1: GOSUB 4000
```

```
1600  PRINT "  NOTICE HOW THE EQUILIBRIUM PREY DEN-  SITY IN YOUR AREA HAS
      LOWERED SLIGHTLY  BY HUNTING PRESSURE."
1610 PAUSE = 500: GOSUB 4000
1620  TEXT :PAUSE = 1000: GOSUB 5000: VTAB 5
1630  PRINT "       YOU HAVE A BOSS WHO WANTS MORE        HUNTERS IN THE AREA S
     O AS TO GET MORE   INCOME INTO THE LOCAL TOWNS."
1640 PAUSE = 500: GOSUB 5000
1650  VTAB 12
1660  REM

1670  REM      THE USER INCREASES HUNTER PRESSURE.
1680  REM

1690  PRINT "     OUT OF THE ORIGINAL 10,000 , HOW     MANY PREY WILL YOU HA
     RVEST NOW?"
1700  PRINT : PRINT : INPUT HP
1710 HP =  INT (HP + .5)
1720  GOSUB 4050
1730  VTAB 2
1740  PRINT "    YOU HAVE CHOSEN TO HARVEST ";HP
1750  PRINT "PREY."
1760  IF HP < 800 THEN  VTAB 15: PRINT "    NOT ENOUGH, SAYS YOUR BOSS. HE
      WANTSMORE HUNTERS (AND MORE INCOME FOR THE    TOWNS)."
1770  IF HP > 4000 THEN  VTAB 8: PRINT "    SUCH A LARGE HARVEST IS TOO RI
     SKY   EVEN TO YOUR BOSS. TRY A SMALLER NUMBER."
1780  IF HP < 800 OR HP > 4000 THEN PAUSE = 2000: GOSUB 4000: GOTO 1650
1790  VTAB 10: PRINT "    LET'S SEE THE EFFECTS OF HUNTERS    HARVESTING "
     ;HP;" PREY."
1800 PAUSE = 4000: GOSUB 5000
1810  GOSUB 4050
1820  POKE  - 16304,0: POKE  - 16297,0
1830  REM

1840  REM      THE LOSS OF A STABLE EQUILIBRIUM POINT DUE TO HUNTER PRESSUR
     E IS SHOWN.
1850  REM

1860 PAUSE = 500: GOSUB 5000
1870  VTAB 22
1880  PRINT "  BY HARVESTING ";HP;" PREY, THE GRAPH"
1890  PRINT "WOULD CHANGE TO LOOK LIKE..."
1900 HTEMP = HP / 10000
1910 HP = HP / 10000:HC = 3:FLAG = 1: GOSUB 4100
1920  GOSUB 4050:HO = HTEMP: VTAB 22
1930  PRINT "  EXCESSIVE HARVEST CAUSED THE EQUILIB-RIUM PREY DENSITY TO
     MOVE FROM HERE..."
1940  GOSUB 4400
1950  FOR I = 1 TO 13
1960  HCOLOR= 3: IF  INT (I / 2) = I / 2 THEN  HCOLOR= 0
1970  HPLOT 200,37 TO 200,45 TO 206,39
1980 PAUSE = 500: GOSUB 5000
1990  NEXT
```

```
2000 PAUSE = 500: GOSUB 4000: VTAB 22
2010  PRINT "      ... TO HERE."
2020  FOR I = 1 TO 13
2030  HCOLOR= 3: IF  INT (I / 2) = I / 2 THEN  HCOLOR= 0
2040  HPLOT 55,135 TO 47,135 TO 53,141
2050 PAUSE = 500: GOSUB 5000
2060  NEXT
2070 PAUSE = 500: GOSUB 4000
2080  HCOLOR= 0
2090  HPLOT 200,37 TO 200,45 TO 206,39
2100 PAUSE = 500: GOSUB 4000
2110  REM

2120  REM      HUNTER PRESSURE IS TAKEN AWAY.
2130  REM

2140  HOME : TEXT
2150 PAUSE = 500: GOSUB 5000: VTAB 7
2160  PRINT "     NOW BECAUSE OF THE SUDDEN LOW         DENSITY OF PREY, YOUR
     BOSS FEARS THAT  HUNTERS WILL WIPE OUT THE PREY COM-      PLETELY."
2170 PAUSE = 1000: GOSUB 5000
2180  VTAB 12
2190  PRINT "     SO HE ORDERS ALL HUNTING TO CEASE,  HOPING THAT THE LACK
     OF HUNTER PRESSURE WILL ALLOW THE PREY TO EVENTUALLY RETURNTO THEIR H
     IGHER EQUILIBRIUM DENSITY."
2200 PAUSE = 500: GOSUB 4000
2210  PRINT "  THE RESULT OF YOUR BOSS'S NEW POLICY  IS THE ORIGINAL GRAPH
     BEFORE HUNTING..."
2220 PAUSE = 500: GOSUB 5000
2230  POKE  - 16304,0: POKE  - 16297,0
2240 HP = 0:HC = 3:FLAG = 1: GOSUB 4100
2250  GOSUB 4050
2260  PRINT "  ALTHOUGH THE UPPER STABLE EQUILIBRIUM POINT RETURNED, THE P
     REY DENSITY IS      STUCK AT THE LOWER EQUILIBRIUM POINT."
2270  GOSUB 4400: HCOLOR= 3
2280  HPLOT 55,118 TO 47,118 TO 53,124
2290 PAUSE = 1000: GOSUB 5000
2300  HCOLOR= 0: HPLOT 55,135 TO 47,135 TO 53,141
2310 PAUSE = 1: GOSUB 4000
2320  PRINT "  DUE TO EXCESSIVE HUNTER PRESSURE, THE PREY DENSITY DROPPED
     TO THE LOWER STABLEEQUILIBRIUM POINT."
2330 PAUSE = 1000: GOSUB 5000
2340  FOR I = 1 TO 13
2350  HCOLOR= 3: IF  INT (I / 2) = I / 2 THEN  HCOLOR= 0
2360  HPLOT 55,118 TO 47,118 TO 53,124
2370 PAUSE = 500: GOSUB 5000
2380  NEXT
2390 PAUSE = 500: GOSUB 4000
2400  VTAB 21
2410  PRINT "  THE PREY DENSITY WILL STAY AT THIS     LOWER EQUILIBRIUM POI
     NT UNTIL OTHER     FACTORS INTERVENE."
2420 PAUSE = 500: GOSUB 4000
```

```
2430  REM .

2440  REM      CONCLUSIONS FROM THE ENTIRE PROGRAM ARE LISTED.
2450  REM

2460  HGR : TEXT : VTAB 1
2470 PAUSE = 500: GOSUB 5000
2480  PRINT "                 CONCLUSION"
2490 PAUSE = 500: GOSUB 5000
2500  VTAB 3
2510  PRINT "     IN THIS MODULE, YOU HAVE:"
2520 PAUSE = 1000: GOSUB 5000: VTAB 5
2530  PRINT "1.  SEEN PREY RECRUITMENT DERIVED FROM     LOGISTIC GROWTH."
2540 PAUSE = 1000: GOSUB 5000: VTAB 8
2550  PRINT "2.  OBSERVED THE PREDATOR FUNCTIONAL       RESPONSE CURVE PLO
 TTED ON THE SAME      GRAPH AS THE PREY RECRUITMENT CURVE."
2560 PAUSE = 1000: GOSUB 5000: VTAB 12
2570  PRINT "3.  IDENTIFIED AND PREDICTED STABILITY     OF PREY DENSITY EQ
UILIBRIUM POINTS."
2580 PAUSE = 1000: GOSUB 5000: VTAB 15
2590  PRINT "4.  CHANGED THE PREDATOR CARRYING          CAPACITY AND OBSER
VED ITS EFFECTS."
2600 PAUSE = 1000: GOSUB 5000: VTAB 18
2610  PRINT "5.  COMPARED RATES AT WHICH DIFFERENT      STARTING PREY DENS
ITIES APPROACHED A    STABLE EQUILIBRIUM POINT."
2620 PAUSE = 1000: GOSUB 5000: VTAB 22
2630  PRINT "6.  WORKED WITH A PARAMETER AFFECTING      AFFECTING PREY REC
RUITMENT, THAT OF     HUNTER PRESSURE.";
2640 PAUSE = 1000: GOSUB 5000
2650  POKE - 16368,0
2660  INPUT "     PRESS -RETURN-";Q$
2670  GOSUB 4050
2680  VTAB 10
2690  PRINT "     I HOPE THIS MODULE HAS BEEN OF SOMEUSE TO YOU."
2700  VTAB 20
2710 PAUSE = 500: GOSUB 5000
2720  PRINT "          THAT'S IT!    BYE."
2730  VTAB 23: END
3999  REM

4000  REM
4010  REM      PAUSE,RETURN,PAUSE,VTAB SUBROUTINE.
4020  REM

4030  GOSUB 5000
4040  GOSUB 5080
4050  HOME
4060 PAUSE = 500: GOSUB 5000
4070  VTAB 21
4080  RETURN
4099  REM
```

```
4100  REM
4101  REM      SUBROUTINE THAT ERASES ONE CURVE WHILE PLOTTING ANOTHER.
4102  REM

4105  HPLOT 23,149
4107 YM = .3
4110 X9 = 23:X8 = 23:X7 = 23:Y9 = 149:Y8 = 149:Y7 = 149
4114 HO = .25 * HO * 2 * 140 / (YM * 50)
4115 HP = .25 * HP * 2 * 140 / (YM * 50)
4120  FOR N = 0 TO 100
4130  HCOLOR= 0
4135  IF Y9 < 0 OR Y9 > 149 GOTO 4240
4140  HPLOT X9,Y9
4150 X0 = X2(N):Y0 = 149 - (149 - HO * N) + Y1(N)
4155  IF Y0 < 0 OR Y0 > 149 GOTO 4240
4160  HPLOT  TO X0,Y0
4170 X9 = X0:Y9 = Y0
4180  IF FLAG = 1 GOTO 4240
4190  IF Y8 < 0 OR Y8 > 149 GOTO 4240
4200  HPLOT X8,Y8
4210 X0 = X2(N):Y0 = 149 - HP * N
4215  IF Y0 < 0 OR Y0 > 149 GOTO 4240
4220  HPLOT  TO X0,Y0
4230 X8 = X0:Y8 = Y0
4240  HCOLOR= HC
4250  HPLOT X7,Y7
4260 X0 = X2(N):Y0 = 149 - (149 - HP * N) + Y1(N)
4270  IF Y0 < 0 OR Y0 > 149 GOTO 4295
4280  HPLOT  TO X0,Y0
4290 X7 = X0:Y7 = Y0
4295  NEXT
4300  RETURN
4301  REM

4400  REM
4410  REM      SUBROUTINE TO REPLOT PREDATOR FUNCTIONAL RESPONSE CURVE.
4420  REM

4425  POKE 28,213
4430  HCOLOR= 5
4440  HPLOT 23,149
4450  FOR I = 0 TO 100
4460  HPLOT  TO X2(I),Y2(I)
4470  NEXT
4480  RETURN
4490  REM
```

```
5000  REM
5010  REM     PAUSE SUBROUTINE.
5020  REM     VARIABLES TO BE PROVIDED:
5030  REM     D  = LENGTH OF PAUSE.
5040  REM

5050  FOR PS = 1 TO PAUSE
5060  NEXT
5070  RETURN
5071  REM

5080  REM
5090  REM     PRESS -RETURN- SUBROUTINE.
5100  REM

5105  POKE  - 16368,0
5110  VTAB 24
5120  INPUT "          PRESS -RETURN- TO CONTINUE";Q$
5130  RETURN
5131  REM

5140  REM
5150  REM      SUBROUTINE THAT BLACKS OUT A RECTANGLE ON THE HGR SCREEN.
5160  REM -VARIABLES THAT MUST BE PROVIDED-
5170  REM      X = STARTING X COORDINATE
5180  REM      Y = STARTING Y COORDINATE
5190  REM      XZ = LENGTH OF RECTANGLE ALONG THE X AXIS.
5200  REM      L = WIDTH OF RECTANGLE ALONG THE Y AXIS.
5210  REM

5220  HCOLOR= 0
5230  FOR TA = 0 TO L
5240  HPLOT X,TA + Y TO X + XZ,TA + Y
5250  NEXT TA
5260  HCOLOR= 3
5270  RETURN
5271  REM

5280  REM  AXES AND UNITS FOR GRAPHS
5290  REM   SUBROUTINE DEVELOPED BY J. SPAIN,MICHIGAN TECH UNIV.,AND B.J.
      WINKEL,ALBION COLLEGE
5300  REM   DEFINE X$=VARIABLE PLOTTED ON X AXIS
5310  REM  DEFINE Y$=VARIABLE PLOTTED ON Y AXIS
5320  REM   DEFINE YM =MAXIMUM UNITS ON THE Y AXIS
5330  REM  DEFINE XM = MAXIMUM UNITS ON THE X AXIS
5335  REM

5340  HCOLOR= 3: SCALE= 1:SC = 1: ROT= 0
5350  REM   LIST OF RESERVED VARIABLES:X,X0,XM,X$,Y,Y0,YM,Y$,Z,ZF,Z0,Z3,L$
      ,SC
```

```
5360  HPLOT 23,0 TO 23,149
5370  HPLOT 25,149 TO 279,149
5380  REM  WRITE VARIABLE NAME ON X-AXIS
5390 Z0 = 0:L$ = X$:X0 = 60:Y0 = 150
5400  GOSUB 5450
5405  IF WRITE = 1 THEN  HOME :PAUSE = 1000: GOSUB 5000: VTAB 22: PRINT "
      ALONG THE Y-AXIS IS THE GROWTH OF THE PREY DENSITY PER YEAR.":PAUSE =
      3000: GOSUB 5000
5410  REM  WRITE VARIABLE NAME ON Y-AXIS
5420 Z0 = 1:L$ = Y$:X0 = 10:Y0 = 140
5425 X0 = 13
5430  GOSUB 5450
5440  RETURN
5450  REM  ALPHANUMERIC CHARACTERS FOR HGR
5460  REM  THE FOLLOWING MUST BE DEFINED
5470  REM  BEFORE ENTERING THE SUBROUTINE
5480  REM  L$ = "CHARACTER STRING"
5490  REM  Y0 = THE INITIAL Y POSITION
5500  REM  X0 = THE INITIAL X POSITION
5510  REM  SET Z0 = 0 IF PRINTING HORIZONTAL
5520  REM  SET Z0 = 1 IF PRINTING VERTICALLY
5530  FOR Z = 1 TO  LEN (L$):Z3 =  ASC ( MID$ (L$,Z,1))
5540  IF Z0 <  > 0 THEN  GOTO 5570
5550  IF Z3 > 64 THEN  DRAW Z3 - 64 AT X0 + (Z - 1) * 7 * SC,Y0: GOTO 5590

5560  DRAW Z3 AT X0 + (Z - 1) * 7 * SC,Y0: GOTO 5590
5570  ROT= 48: IF Z3 > 64 THEN  DRAW Z3 - 64 AT X0,Y0 - (Z - 1) * 7: GOTO
      5590
5580  DRAW Z3 AT X0,Y0 - (Z - 1) * 7
5590  ROT= 0: NEXT Z
5600  RETURN
5601  REM

5610  REM  SCALE AND PLOT POINT FOR DEFINED X AND Y
5620  REM  FOR LINE PLOT MAKE ZF=1
5625  REM

5630 X0 = 23 + X * 256 / XM
5640 Y0 = 149 - Y * 140 / YM
5650  IF X0 > 279 OR X0 < 0 OR Y0 > 149 OR Y0 < 0 THEN  GOTO 5680
5660  IF ZG = 1 THEN  HPLOT  TO X0,Y0: GOTO 5680
5670  HPLOT X0,Y0: IF ZF = 1 THEN ZG = 1
5680  RETURN
9995  REM
```

```
9996  REM     DATA STATEMENTS FOR COORDINATES OF PREY RECRUITMENT AND PRED
   ATOR FUNCTIONAL RESPONSE CURVE.
9997  REM

10000  DATA  23,149,149,25,144,148,28,139,147
10010  DATA  30,135,143,33,131,139,35,126,132
10020  DATA  38,122,125,40,118,118,43,114,110
10030  DATA  46,110,103,48,107,96,51,103,90
10040  DATA  53,99,84,56,96,80,58,92,76
10050  DATA  61,89,72,63,86,69,66,83,66
10060  DATA  69,80,64,71,77,62,74,74,61
10070  DATA  76,71,59,79,68,58,81,66,57
10080  DATA  84,63,56,87,61,55,89,59,54
10090  DATA  92,57,53,94,54,53,97,52,52
10100  DATA  99,51,52,102,49,51,104,47,51
10110  DATA  107,45,51,110,44,50,112,42,50
10120  DATA  115,41,50,117,40,49,120,39,49
10130  DATA  122,37,49,125,37,49,127,36,49
10140  DATA  130,35,48,133,34,48,135,34,48
10150  DATA  138,33,48,140,33,48,143,32,48
10160  DATA  145,32,48,148,32,48,151,32,48
10170  DATA  153,32,47,156,32,47,158,32,47
10180  DATA  161,33,47,163,33,47,166,34,47
10190  DATA  168,34,47,171,35,47,174,36,47
10200  DATA  176,37,47,179,37,47,181,39,47
10210  DATA  184,40,47,186,41,47,189,42,47
10220  DATA  191,44,47,194,45,47,197,47,47
10230  DATA  199,49,47,202,50,47,204,52,47
10240  DATA  207,54,47,209,57,47,212,59,46
10250  DATA  215,61,46,217,63,46,220,66,46
10260  DATA  222,68,46,225,71,46,227,74,46
10270  DATA  230,77,46,232,80,46,235,83,46
10280  DATA  238,86,46,240,89,46,243,92,46
10290  DATA  245,96,46,248,99,46,250,103,46
10300  DATA  253,106,46,255,110,46,258,114,46
10310  DATA  261,118,46,263,122,46,266,126,46
10320  DATA  268,131,46,271,135,46,273,139,46
10330  DATA  276,144,46,279,149,46
```